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Lighthouse Protection Studies, New England

Highland Light Station North Truro, Massachusetts

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13. ABSTRACT *(Maximum 200 words)* This report is the culmination of a study performed under a Memorandum of Understanding (MOU) between the U.S. Coast Guard and the U.S. Army Corps of Engineers. Highland Light Station is the first of six lighthouses to be investigated. The Corps has agreed to study these six lighthouses and make recommendations to the Coast Guard regarding the best method to protect the structures. The following areas were analyzed in the study: geology, ecology, historical shoreline changes, wave climate, coastal processes, and erosion processes. Highland Light Station is located 10 miles south of Provincetown, in North Truro, MA. Many recommendations were presented. One recommendation was to set up a survey program on a six month basis, which was important to the success of any plan to protect the lighthouse. The preferred recommendation was to move the existing lighthouse to a new location or demolish the lighthouse and construct one in a new location. The estimate cost for the relocation or demolish/construction is $2,400,00. Based on historical changes, the report predicts the future erosion of the cliff using two scenarios. Using the 'most likely case', the lighthouse would be in danger in 1998, critical danger in 2018. 'Worst case', the lighthouse would be in danger in 1989, critical danger in 1995.

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HIGHLAND LIGHT STATION, NORTH TRURO, MA - CORPS OF ENGINEERS, NOVEMBER 2, 1987

UNITED STATES COAST GUARD, FIRST DISTRICT

LIGHTHOUSE PROTECTION STUDIES, NEW ENGLAND

HIGHLAND LIGHT STATION
NORTH TRURO, MASSACHUSETTS

JULY 1988

U.S. ARMY CORPS
OF ENGINEERS

NEW ENGLAND DIVISION

HIGHLAND LIGHT STATION, NORTH TRURO, MA
EROSION STUDY

EXECUTIVE SUMMARY

The U.S. Coast Guard is concerned about erosion problems which are threatening six of their lighthouses in New England. Under a memorandum of understanding (MOU), the Corps has agreed to study these six lighthouses and make recommendations to the Coast Guard regarding the best method to protect the structures. This report reflects Corps of Engineers findings at one of these six stations, namely Highland Light.

Highland Light Station is located on the eastern shore of Cape Cod, in North Truro, MA, approximately 10 miles south of Provincetown. The structure sits on the upland atop a 120 foot high cliff. There is little or no vegetation on the cliff face directly below the structure, which probably contributes to the instability of the cliff face. The original site, designated in 1797, contained 10 acres, at the present time, there are only 4 acres remaining of the original site.

The following areas were analyzed in the study to aid in the prediction of future conditions and the selection of alternatives:

- Geology
- Ecology
- Historical Shoreline Changes
- Wave Climate
- Coastal Processes
- Erosion Processes.

The erosion at Highland Light Station has been continuous since it was built in 1797 with its center 510 feet from the cliff. Since that time, erosion has proceeded unevenly to January, 1988 when the center was 143 feet from the cliff at its closest point. It is estimated that the lighthouse would be in danger when its center is 100 feet from the cliff and in critical danger when it is 50 feet from the cliff. Based on historical changes, the report predicts the future erosion of the cliff using two scenarios. Using the "most likely case", the lighthouse would be in danger in 1998 and in critical danger in 2018. Assuming the "worst case", the lighthouse would be in danger in 1989 and in critical danger in 1995.

The Coast Guard has been conducting a detailed monitoring survey program for the past five years. The results from this program have been very useful in the analysis of the conditions in the area. Unfortunately, this survey program has been discontinued. One recommendation is to set up a survey program and continue with the surveys at least on a six month basis. The surveys are important to the success of any plan to protect the lighthouse. It is important that the Coast Guard carefully track the rate of bank recession so that they will have adequate time to undertake appropriate action.

This report presents plans to stabilize the bank and thereby prolong the useful life of the lighthouse. However, as reported, even if the stabilization plans are implemented, the preferred recommendation is to move the existing light structure to a new location or the Coast Guard could demolish the existing light structure and construct one in a new location.

The stabilization plans will only prolong the life of the light structure in its present location.

The final choice of alternatives will be left up to the Coast Guard. The report contains cost estimates for most of the stabilization alternatives as well as the alternatives for moving the existing structure and constructing a new one. Preliminary cost estimates indicate an order of magnitude of first costs for the relocation or the demolish/construction alternatives respectfully to be $800,000 and $1,600,000. Detailed engineering design and cost estimates would be necessary by the Coast Guard once it decides which of the alternative plans is to be implemented. An Environmental Assessment is also a prerequisite to project implementation.

It is recommended that the Coast Guard take the necessary steps to either relocate the lighthouse or demolish it and reconstruct a new lighthouse based on the optimal technically, economically and environmentally feasible and publicly acceptable solution to the erosion problem at Highland Lighthouse.

It is further recommended that the Coast Guard reinstitute the survey program to monitor the evolution of the erosion at the light station. Appendix 1 provides details on ways to update and improve the original survey program. The survey monitoring program will track the rate of bank erosion in order to have adequate time to undertake the selected plan.

Concurrent with the reestablishment of the survey program, studies could be initiated to determine if methods of vegetation and structural bank stabilization are feasible in order to prolong the life of Highland Lighthouse in its present location.

HIGHLAND LIGHT STATION, NORTH TRURO, MA
EROSION STUDY

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INTRODUCTION

This report is the culmination of a study performed under a Memorandum of Understanding (MOU) between the U. S. Coast Guard and the U.S. Army Corps of Engineers. Highland Light Station is the first of six lighthouses to be investigated under this MOU. The severe erosion occurring at this lighthouse threatens to destroy this historically significant structure. The Coast Guard requested that the Corps study the situation and report upon the following items:

- natural setting
- historical analysis of shoreline changes
- wave climate and coastal processes
- erosion processes and critical areas
- a monitoring survey program
- prediction of future conditions
- plan formulation and evaluation
- findings and recommendations

NATURAL SETTING

Highland Light Station, owned and operated by the U.S. Coast Guard, is located on the eastern shore of Cape Cod, approximately 10 miles south of Provincetown, in North Truro, MA. (See location map, Plate 1.) A Plot Plan of the Lighthouse site is provided as Plate 2. One mile north of the lighthouse, access is provided to Highland Beach which lies below the cliff in front of the lighthouse. Between this access and the Cape Cod National Seashore land abutting the Coast Guard property are a few homes. On the abutting National Seashore land there is a walkway leading to an overlook 1/4 mile north of the lighthouse. In May 1987, the walkway was closed permanently due to a cliff failure which occurred earlier that spring. At the overlook is an indentation in the shoreline which is typical of the many low spots in the land where water drains over the bluff causing surface erosion. The cliff in front of the lighthouse lies at about a 40 degree angle from the horizontal. Cables and pipes hang from the upper portions of the bluff which were at the locations of outbuildings that have since fallen into the sea.

To the south and west of the lighthouse lies a golf course, with fairways set back about 100 yards from the bluff except at one point a few hundred feet south of the lighthouse where they closely approach the bluff. This spot presents a significant indent of the cliff although it is far enough away from the lighthouse so as not to endanger it. To the south of the golf course there is an Air Force installation.

The east coast of Truro extends in a northwest to southeast direction. Nearshore bars, in front of the lighthouse area, extend in a north to south orientation, so they intersect the coast at about 25 degree angles. Their spacing varies but it is about 200 feet on average. The erosion of the coast near Highland Light Station is extremely dynamic and depending upon the severity of the storms, the bars undoubtedly change considerably.

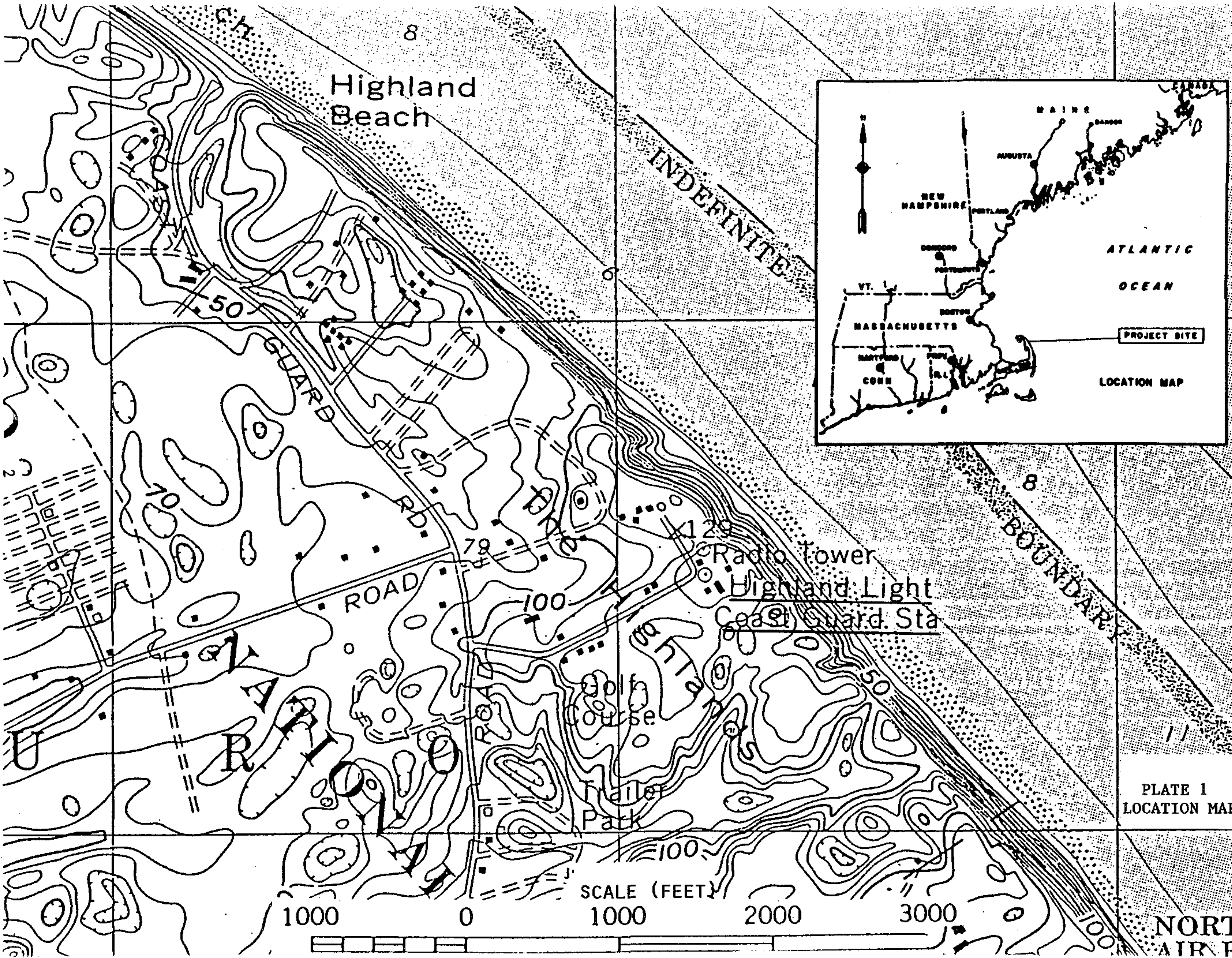


PLATE 1
LOCATION MAP

Highland Light Station is located approximately 120 feet above the ocean on the edge of an eroding cliff. The instability is due to the physical composition of the cliffs and their location facing the sea. The unstable nature of the lighthouse site is evidenced by the fact that only four acres remain of the original 10 acre site designated in 1797. A survey monitoring program, conducted by the Coast Guard reveals that within the past 5 years, retreat of the cliff top has proceeded at a rate of 4 to 5 feet per year. The tower is now approximately 143 feet from the edge of the bluff. A summary of the geology of the outer Cape Cod followed by a more detailed discussion of the geology of Highland Light Station will contribute to a better understanding of the reasons for the rapid rate of cliff retreat in the vicinity of the lighthouse.

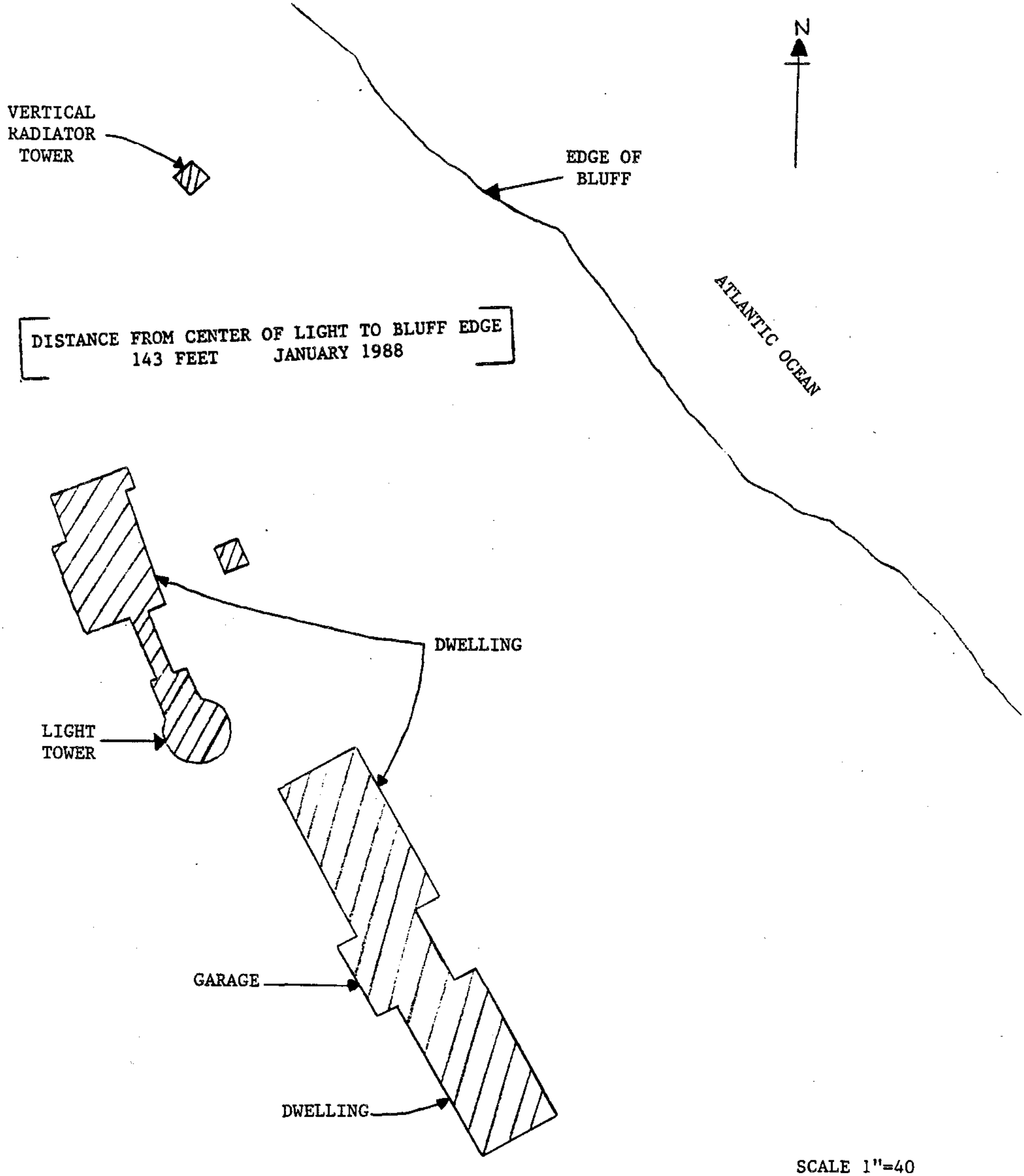
GEOLOGY

Eastern Cape Cod from Chatham to the Province Lands, known as the "Outer Cape", is composed of unconsolidated sands, gravels, silts and clays deposited by meltwater streams draining wasting glacial ice. Approximately 80 to 100 thousand years ago continental ice sheets of the Wisconsin Stage of the Pleistocene Epoch advanced over New England. About 20 to 26 thousand years ago, this ice moved to the areas now occupied by the islands of Martha's Vineyard and Nantucket. Approximately 15 thousand years ago, following a period of standstill, the ice front migrated northerly due to climatic warming and reached the area of the present day Cape Cod. A long period of ice melting and standstill ensued and during that time, large quantities of sediment were deposited from the wasting ice margin.

Figure 1 shows that the ice front was lobate in shape. Because of the varied topography of the continental shelf, the retreat of the ice lobes from the Cape area was uneven. The South Channel lobe occupied a lower elevation of the shelf area and consequently extended further south and remained longer in place than the other lobes during the retreat of ice during deglaciation. As the Cape Cod Bay lobe retreated northward, the South Channel lobe remained in place. In this fashion a large proglacial lake was formed bounded by the Cape Cod Bay lobe on the north, the South Channel lobe on the east, and previously formed glacial sediments on the south and west.

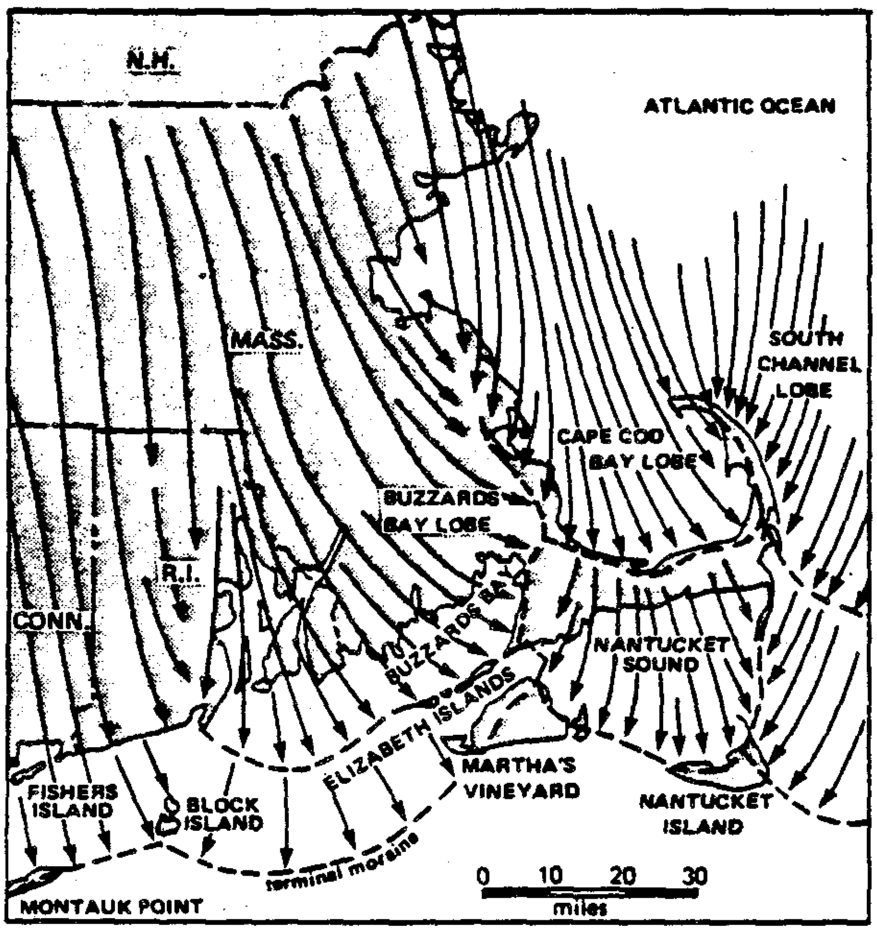
Sediments transported by streams flowing off the wasting ice were carried westerly and deposited as outwash plain sediments into the proglacial lake. When the South Channel lobe retreated from the area due to continued climatic warming, the proglacial lake was able to drain to the north and deposition in the area, and thus the glacial formation of Cape Cod, was completed.

Several sequences of outwash plain sediments (known as plains) are recognized on the outer Cape. Highland Light Station is situated on the Highland Plain fronting on the outer shore and mapped on the North Truro Quadrangle, Barnstable County, Massachusetts. A more detailed discussion of the geology of the Highland Plain follows.



PLOT PLAN: HIGHLAND LIGHT STATION, NORTH TRURO, MA
8 JULY 1985

FIGURE 1 - ICE LOBES OF THE WISCONSIN STAGE OF GLACIATION



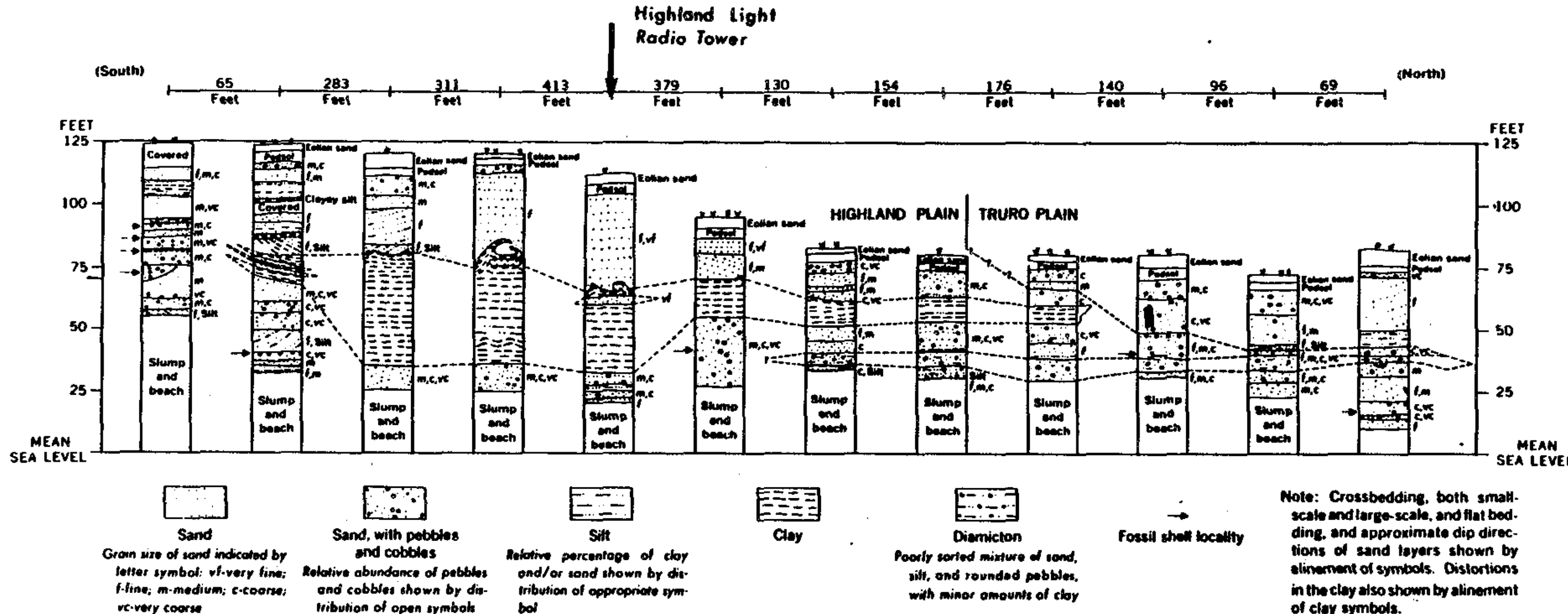


FIGURE 2
DIAGRAMMATIC MEASURED SECTIONS AT HIGHLAND (CAPE COD) LIGHT

A series of measured sections of the wavecut cliff near Highland Light Station illustrating the Highland Plain deposits (with some overlying Truro Plain deposits) is seen in Figure 2 (after Koteff, 1967). In general, the stratigraphy of much of the Highland Plain can be considered to consist of three parts. At the base of the cliff outcrops of iron stained medium to coarse grained sand are overlain by layers of dark gray clay and silty clay with some distortions visible, and this is in turn overlain by fine to very fine grained layered sands capped by podsol and eolian sand.

The lowermost sands and immediately overlying clays and silts are interpreted as a lacustrine (lake) sequence in which sediments were deposited in the proglacial lake by streams pouring from the melting glacial ice. The upper sequence of finer sands are seen by most workers as fluvial in nature formed as streams flowed over the earlier formed lake deposits.

The generalized sequence described above varies significantly along the exposure, indicative of the very complex and diverse environment of deposition in place at the time of the formation of the sediments. While a stratigraphy corresponding very closely to the general sequence is found in a 700 foot horizontal section situated 300 feet north of the lighthouse, the geology immediately below the lighthouse is more complicated. This section has been mapped as 50 feet of slump and beach deposits overlain by 40 feet of mixed sediments consisting of infrequent silty layers with interbedded medium to coarse sand containing some pebbles and cobbles. This is in turn overlain by 20 feet of interbedded layers of medium to coarse sand, poorly sorted sand pebbles and minor amounts of clay, and beds of mixed silt and clay. The sequence is capped by 15 feet of medium to fine sand overlain by podzol.

Of special significance to this study is the presence of large amounts of clay in the middle of the stratigraphic sequence in the vicinity of Highland Light Station. These impermeable layers of clay trap infiltrating rainwater and retain it or channel it to points of drainage from the cliff front. These areas of retention and drainage outlets are sites of potential extraordinary erosion problems. This aspect of the geology will be discussed further under the section on Erosion Processes. Also of special interest is the obvious, but significant, point that the geology of the Highland Light Station area consists of <u>unconsolidated</u> stratified sediments and thus is very susceptible to erosion from wind/wave attack or stress induced by gravity.

ECOLOGY

For purposes of this study the most important ecological characteristics examined were soils and vegetation. Animal life, vertebrates or invertebrates, apparently have no significant effect on the kind and rates of cliff erosion in the area and are thus not discussed here.

Soils

The generalized soil type on Cape Cod is termed by soil scientists as a podzol soil which forms in areas with cool moist temperate climates. It is a zonal soil covered with a surficial layer of humus overlying a gray leached zone of sand which in turn overlies a layer of dense compact soil colored red-brown to yellow-brown which is dependent upon concentrations of iron oxide that are leached by percolating rainwater from the overlying horizon. If sufficiently dense and compact, the iron oxide zone is known as hardpan. This layer overlies the parent sand material.

Thick outwash plain deposits in the Highland Light Area allows for the potential of good soil development. Where clay is present in the sand, common in the vicinity of Highland Light, leaching is inhibited and a soil somewhat more fertile than other outwash plain soil is developed. The Soil Conservation Service Maps the soil in the upland areas by Highland Light as "dry coarse sandy soil on slopes less than 15%". The soils are well drained except where layers of clay or hard pan inhibit drainage.

Vegetation

Prior to settlement by the Pilgrims, most of the entire Cape, including the Truro area, was heavily forested with pine and oak being the most common trees. With the arrival of the colonists, land clearing; burning; poor agricultural practises and grazing by animals markedly reduced the vegetation, and by the mid 19th century, the Cape was bare of most forest. Eventually however, more conservative voices were heeded and the careless use of the land ceased and the species which survived the land clearing have reestablished themselves and in many areas a thick scrub forest of pitch pine-oak is found.

Although there is not an excess of trees in the area immediately surrounding Highland Light, the general area is considered as Upland Forest. Abandoned fields and pastures make up a temporary habitat known as a succession area. These areas are characterized by wild flowers, woody shrubs and vines, and pitch pine, scrub oak, sassafras and black oak. The Upland Forest is characterized by pitch pine-oak, scrub oak, other hardwoods as well as heaths, shrubs and bushes.

The area immediately adjacent to Highland Light incorporates characteristics of both Upland Forest and succession areas. No attempt was made to accurately define the precise types of vegetation growing there. Figure 3 shows that the area is well covered with low scrub type material on the upland areas. The cliffs are vegetated in part and generally erosion is least where this vegetation occurs (see Figure 4). Due to the well established mat of vegetative growth on the uplands bordering the bluff, little erosion is caused by wind deflation. Successful efforts by the National Park Service have kept pedestrian and vehicular traffic to a minimum in vicinity of the Light and thus the vegetation has continued to flourish and provide its protective cover.

INTERNAL DRAINAGE

The stratigraphic section at Highland Light (see Figure 2) discussed in the section on Natural Setting clearly shows the large amount of clay present in the stratigraphy of the cliff on which the lighthouse sits. It is the presence of this clay which contributes to internal drainage and seepage from the cliff face. This drainage and seepage in turn contributes in great measure to the rapid, erratic and occasionally catastrophic erosion from slope failure which occurs in the area.

Clay bearing sediments are more impermeable than coarse grained sediments. The purer the clay, the more impermeable is the layer. At Highland Light the clay is for the most part very pure. It is attested that the various Indian tribes which inhabited the area used this clay for pottery and other utensils.

FIGURE 3 - PHOTO SHOWING LOW SCRUB MATERIAL ON UPLAND AREAS

FIGURE 4 - PHOTO SHOWING VEGETATION ON CLIFFS

As can be seen in Figure 2, the clay in the cliff is of variable thickness and distribution but is certainly an abundant and common sedimentary layer. As precipitation falls on the upland area it will infiltrate the eolian (wind blown) layer and soils present and percolate through the sandy layers until clay is encountered. The clay layer presents an impermeable barrier to the infiltrating water causing it to move parallel to the clay layer rather than through it. This generally horizontal movement will commonly cause water to move to the cliff face and drain and seep down the cliff face from the point of exit. Figure 5 well illustrates this phenomenon.

As the water is moving along the clay layers it tends to reduce the coefficient of friction between clay layers or clay and adjacent sand or silt layers. Such a reduction of friction (becoming slippery in every day terms) will greatly increase the possibility of mass wasting in the form of land slides or debris slides as large chunks of the cliff face, already oversteepened by undercutting by waves, will suddenly fall as gravity overcomes the reduced force of friction. Additionally, the internal drainage will add weight to the cliff sediments and therefor increase the risk of slope failure. Ice crystal growth as the water trapped in the sediments freezes in cold temperature will further reduce the strength of the sediments and further increase the potential of down slope movement.

Rain water runs downhill, therefore, the analysis of runoff reduces to a study of topography. As the name Highland indicates, it is a high point where land slopes downward in all directions. This would tend to cause erosion, but fortunately the land slopes gently, is well vegetated, and is composed of porous sand. The porous sand allows the rain water to soak into the ground reducing the amount of erosion caused by flowing surface water. Few obvious surface water erosion scars are visible in the Highland Light area.

The runoff from the east side of the lighthouse must flow over the cliff. It does not appear to be causing much erosion because there is not much distance in front of the lighthouse over which the runoff can accumulate. There are two low spots which are about 1,000 feet away from the lighthouse along the cliff in either direction. These appear to channel water over the cliffs and are locations of considerable erosion. However, they are far enough away that they are not endangering the lighthouse. Runoff from behind the lighthouse drains to the west since the land slopes that way. For example, the elevation of Highland Road varies from over 130 feet at the lighthouse to about 40 feet where it meets Route 6. The drainage from the northern side of the lighthouse station follows the road and eventually empties into Village Pond in North Truro. Runoff from the area south of the lighthouse also arrives at Village Pond but does so by a different and more southerly route. To summarize, other than by feeding ground water and thereby contributing to erosion, surface runoff is not a major cause of the erosion problem at Highland Light.

HISTORICAL ANALYSIS OF SHORELINE CHANGES

Since it was first built in 1797, the erosion at Highland Light Station has been continuous. Information on the erosion rate is available from 3 sources: 1) land surveys at the station 2) various studies of outer Cape Cod 3) erosion measurements made by the Coast Guard.

FIGURE 5 - PHOTO SHOWING CLAY LAYER IN CLIFF

A search of the USCG engineering files found field surveys of the Highland Light Station done in 1796, 1877, 1885, 1903, 1952 and 1961. The 1961 survey was a plane table. Distances from the center of the lighthouse to the edge of the bluff were measured along a line parallel to the southern property boundary. The results of these surveys, combined with 1985 measurements from the USCG survey monitoring program and 1988 measurements taken by the Corps while performing this study, are shown in Table 1. This data shows that the erosion rate has historically been between 1 and 2 feet per year. Since 1961 it has increased to over 3 feet per year. Since 1982, the erosion in the area has increased again to approximately 4 to 5 feet per year. Figure 6 shows the surveys in the form of a shoreline change map. The 1877, 1885 and 1903 surveys overlap. Although this was a period of low erosion, the overlap shows some inaccuracy in the surveys. Even with the discrepancies taking into consideration, the map as a whole does give a picture of the erosion over time.

A number of researchers have studied the erosion of Cape Cod. Lawrence Gatto of the U. S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory under contract to the New England Division of the Corps did an analysis of the erosion rate of outer Cape Cod using aerial photos. He obtained photos taken in 1938, 1962, 1971, and 1974. Average annual cliff retreat was calculated for the time periods between photos. For 1938-1962, 1962-1971, and 1971-1974 retreat rates were 2.8, 0.1, and 15.4 feet per year respectively. Aerial photos are most likely not as accurate as surveys since they are relatively small scale.

In 1958 Zeigler, Tasha, and Geise replicated surveys of outer Cape Cod done between 1887 and 1889 by Marindin of the U. S. Coast and Geodetic Survey. The station closest to Highland Light Station is about 700 feet to the north. It had an average erosion rate of 1.1 feet per year over the time period. Other investigators, some of whom are listed in the bibliography, have written about the erosion rates on outer Cape Cod; but the above are the best sources of quantitative historical information about Highland Light Station.

The Coast Guard has maintained an erosion record at Highland Light Station for a number of years. An analysis of this survey information as presented in Appendix 1, clearly shows that the erosion is not continuous but occurs irregularly as chunks fall down the cliff. The erosion rate appears to vary from about 5 feet per year to about 1 foot per year, depending on when large chunks fall at a given spot. At station F, for example, a 16 foot chunk of cliff fell off in October 1985.

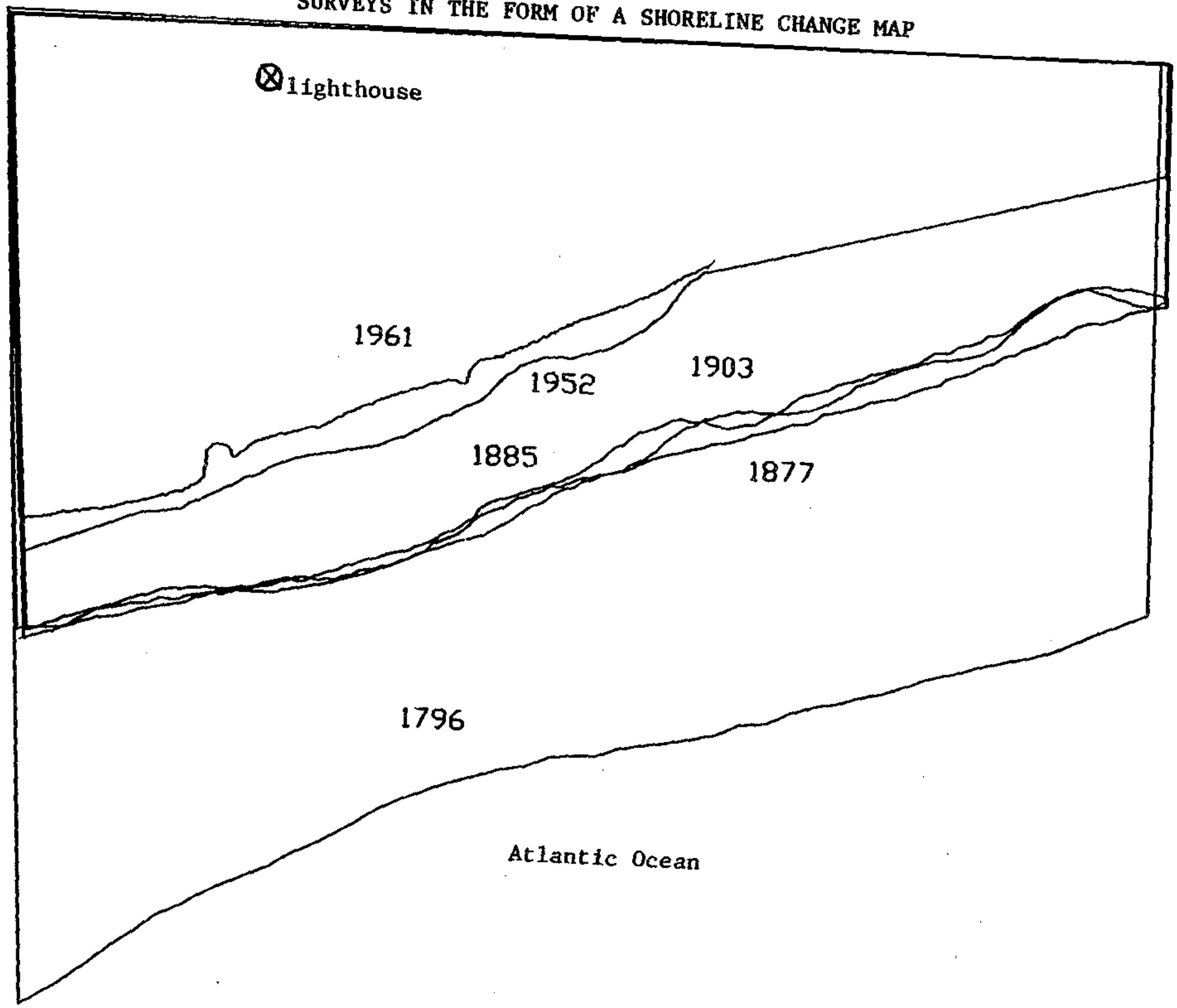
The purpose of looking at past erosion rates is to predict the future erosion rate. Historically, over the long run, the erosion rate has been less than 2 feet per year. This is due to the fact that there are more slow years over a longer period of time. However, averaging the erosion over 5 or so years at a time yields a much higher rate of 4 to 5 feet per year. Sea level rise or increased human activity close to the bluff may be increasing this value. Gatto's 1971-1974 rate shows erosion of 15.4 feet per year while the Coast Guard monitoring program shows average losses of up to 5 feet per year and chunks of up to 15 feet being lost at one time.

TABLE 1

SUMMARY OF SURVEY DATA

YEAR	YEARS	DISTANCE	EROSION	RATE
1796		510		
	81		175	2.2
1877		335		
	8		-1	-0.1
1885		336		
	18		26	1.4
1903		310		
	49		70	1.4
1952		240		
	9		8	0.9
1961		232		
	24		72	3.0
1985		160		
	3		17	5.7
1988		143		

FIGURE 6
SURVEYS IN THE FORM OF A SHORELINE CHANGE MAP



Henry David Thoreau, the noted philosopher of Walden Pond, wrote a book based on his travels to Cape Cod in 1849 and 1855. In the book, he devotes an entire chapter to Highland Light. He made some measurements in the vicinity of the lighthouse with surprising accuracy. Using a level and some other tools, borrowed from a carpenter shingling a nearby barn, Thoreau found the cliff in front of the lighthouse to make an angle of 40 degrees with the horizontal. This value agrees with the angle found in 1988 using a hand inclinometer. Thoreau estimated the distance from the bank to the lighthouse to be 20 rods or 320 ft. In 1877 it was 333 feet to the center of the lighthouse but Thoreau probably measured to the edge of the structure. There was a house which has since been demolished in front of the lighthouse so his number is probably accurate. Thoreau also mentions that at one spot in front of the lighthouse the bank had receded 40 feet from October to June. While this number seems high it cannot be discounted considering the accuracy of his other measurements. He mentions the overall erosion rate was less than 6 feet per year.

Thoreau observed that when the lighthouse was built in 1798 it was estimated to last 45 years, but a structure was still there in nearly the same spot in 1855 as it is today. (It was rebuilt in the same location in 1857.) Thoreau made the following pertinent quote: "Any conclusion drawn from the observations of a few years, or even one generation, are likely to prove false, and the Cape may balk expectation by its durability."

During the Blizzard of 1978, 18 feet of bluff was lost. Generally, the erosion does not occur during storms. The storm tends to erode the base and steepens the bank. The steepened bank may stand for months or years before a chunk falls off. In the spring of 1987, approximately 10 feet fell off near the National Park Service overlook which is a few hundred yards north of the lighthouse. It fell following a period of heavy rains which apparently weakened the bluff. However, there was an storm in January 1987, with a return period of approximately 20 years, which most likely contributed to the fall. The above examples point out the extreme variability of the erosion rate of the area. The amount of erosion which occurs at any time seems to be dependent on the location of weak spots in the bluff.

WAVE CLIMATE AND COASTAL PROCESSES

The Coastal Engineering Research Center (CERC) has developed Sea State Engineering Analysis System (SEAS) which is a data base containing the sea conditions along the U. S. coast at 3 hour intervals for the years 1956-1975. The data was hindcast using actual meteorological conditions for the time period. Atmospheric pressure differences were used to generate wind speed at a 19.5 meter elevation. Wind speed was then used by a numerical model to simulate wave generation. Available data includes significant wave height, peak spectral period, and wave direction. There were three phases to the SEAS study. Each phase brought waves closer to the shoreline. Phase III, used for the Highland Light study, transformed deep water waves into shallow water and included long waves. The location closest to Highland Light Station is at 69.48 degrees west latitude and 42.11 degrees north longitude. This is about 26 nautical miles from from Highland Light Station at a bearing of about 85 degrees from true north.

FIGURE 7 - TYPICAL SEAS OUTPUT

PERCENT OCCURRENCE (X1000) OF HEIGHT AND PERIOD BY DIRECTION
22.5 DEGREES ABOUT 90.0 DEGREES AZIMUTH

STATION: A2016 42.11N/ 69.48W — NO. CASES: 276; % OF TOTAL: 4.

HEIGHT IN METERS	PEAK PERIOD (IN SECONDS) 0.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.	19.0 LONGER	TOTA
0.0-0.9	207	1042	183	574	51	203	75	.	.	.	233
1.0-1.9	.	148	542	297	59	210	154	.	.	.	141
2.0-2.9	.	.	155	287	11	66	83	.	.	.	60
3.0-3.9	.	.	23	263	5	11	6	.	.	.	30
4.0-4.9	.	.	.	35	22	.	.	.	.	.	5
5.0-5.9	.	.	.	.	6	.	.	.	.	.	
6.0-6.9	.	.	.	.	3	.	.	.	.	.	
7.0-7.9	.	.	.	.	.	.	.	.	.	.	
8.0-8.9	.	.	.	.	.	.	.	.	.	.	
9.0-9.9	.	.	.	.	.	.	.	.	.	.	
10.0+	.	.	.	.	.	.	.	.	.	.	
TOTAL	207	1190	903	1456	157	490	318	0	0	0	

MEAN HS(M) = 1.3 LARGEST HS(M) = 6.4 MEAN TP(SEC) = 6.7

Various tables are available from the SEAS data set. Figure 7 is typical output. It contains the percent occurrence of waves of given heights, periods and directions.

For each direction, SEAS calculates the percent of the waves coming from that direction, average significant wave height, maximum significant wave height and average peak spectral period over the twenty year period. Although these data are for a location 26 nautical miles from Highland Light Station, the wave characteristics of storm waves at Highland Light Station should be similar.

Table 2 is a summary of the wave data for the SEAS location closest to Highland Light Station. It shows the most common waves to be from the south and southwest. These are usually fair weather waves since the average wave size from these directions is fairly small. Waves from the west are more common than waves from the east since the prevailing wind is from the west. Since Highland Light Station is exposed to the ocean only on the eastern side, waves from the west have no effect in the area. In general, the times when the waves are from the west at the SEAS site are periods on relative calm at the Highland Light Station. The largest waves come from the east which is to be expected since this direction has the largest fetch.

A wave refraction analysis of the Highland Light Station area was done using RCPWAVE. RCPWAVE is a computer program which solves Berkhoff's mild slope equation using an iterative finite difference scheme. It calculates refraction and diffraction effects, assuming linear waves. The program does not include energy dissipation except in the surf zone where it is introduced when the waves break. RCPWAVE was developed by the U. S. Army Corps of Engineers Coastal Engineering Research Center (CERC) and is described in CERC Technical Report 86-4.

RCPWAVE requires bathymetry data, deep water wave height, wave period, and deep water wave direction as input. The bathymetry data was obtained from nautical chart number 1208 (1973 edition). Depths were found at points 3,333 feet apart for a distance of 10.7 statute miles in the longshore direction and 6.9 miles in the offshore direction. A total of 216 depths were determined from the chart. A four point interpolation routine written for this study, expanded this grid to an 86 by 56 matrix whose points are 666 feet apart. This 4,816 point grid was used for program execution.

Using SEAS data, a wave height of 20 feet with a period of 12 seconds was selected for analysis. This is a large wave for Cape Cod, however, waves of over 26 feet were indicated by SEAS. Although a period of 10 seconds is more likely to be associated with a 20 foot wave, a 12 second period occasionally occurs with 20 foot waves. The 12 second wave implies a longer wave length which reduces the possibility of instability in the numerical model.

It was assumed that the waves 7 miles from the shore were the same as those at the SEAS station. The water depth is such that there should be little energy dissipation or shoaling over this 20 mile distance. Any effects caused by George's Bank were not included in the model because George's Bank is too far away to be treated by RCPWAVE. Ray tracing routines have been used on this problem by a number of investigators. (Swanson & Spaulding 1978).

TABLE 2

HIGHLAND LIGHT SEAS DATA

		%	hs(ave)	hs(large)	tp
			METERS		SEC
0.0	N	4	1.7	6.9	5
22.5	NNE	4	1.6	7	5.5
45.0	NE	4	1.6	8.4	5.6
67.5	ENE	3	1.6	8.7	5.1
90.0	E	4	1.3	6.4	6.7
112.5	ESE	3	1.2	6.8	4.7
135.0	SE	3	1.2	7	4.4
157.5	SSE	3	1.2	6.8	4.7
180.0	S	13	1	8.8	7
202.5	SSW	11	0.9	9.3	5.4
225.0	SW	7	0.9	7.4	3.8
247.5	WSW	7	0.9	7.2	3.9
270.0	W	7	1.1	5.4	4.1
292.5	WNW	8	1.3	5.6	4.4
315.0	NW	8	1.7	6.2	5.2
337.5	NNW	5	1.7	6.1	5.1

FIGURE 8

Wave Refraction

Waves from the north

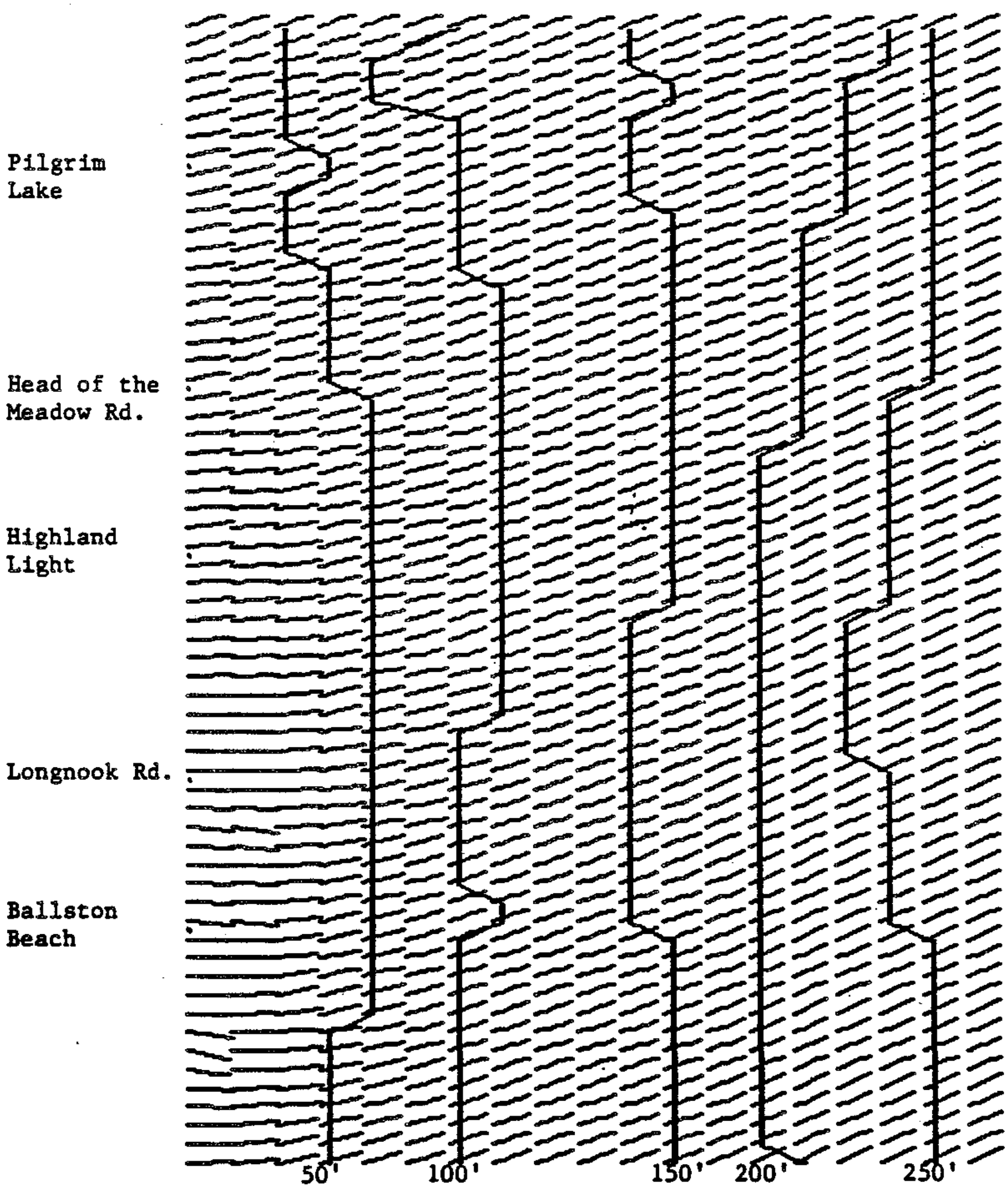


FIGURE 9
Wave Refraction

Waves from the northeast

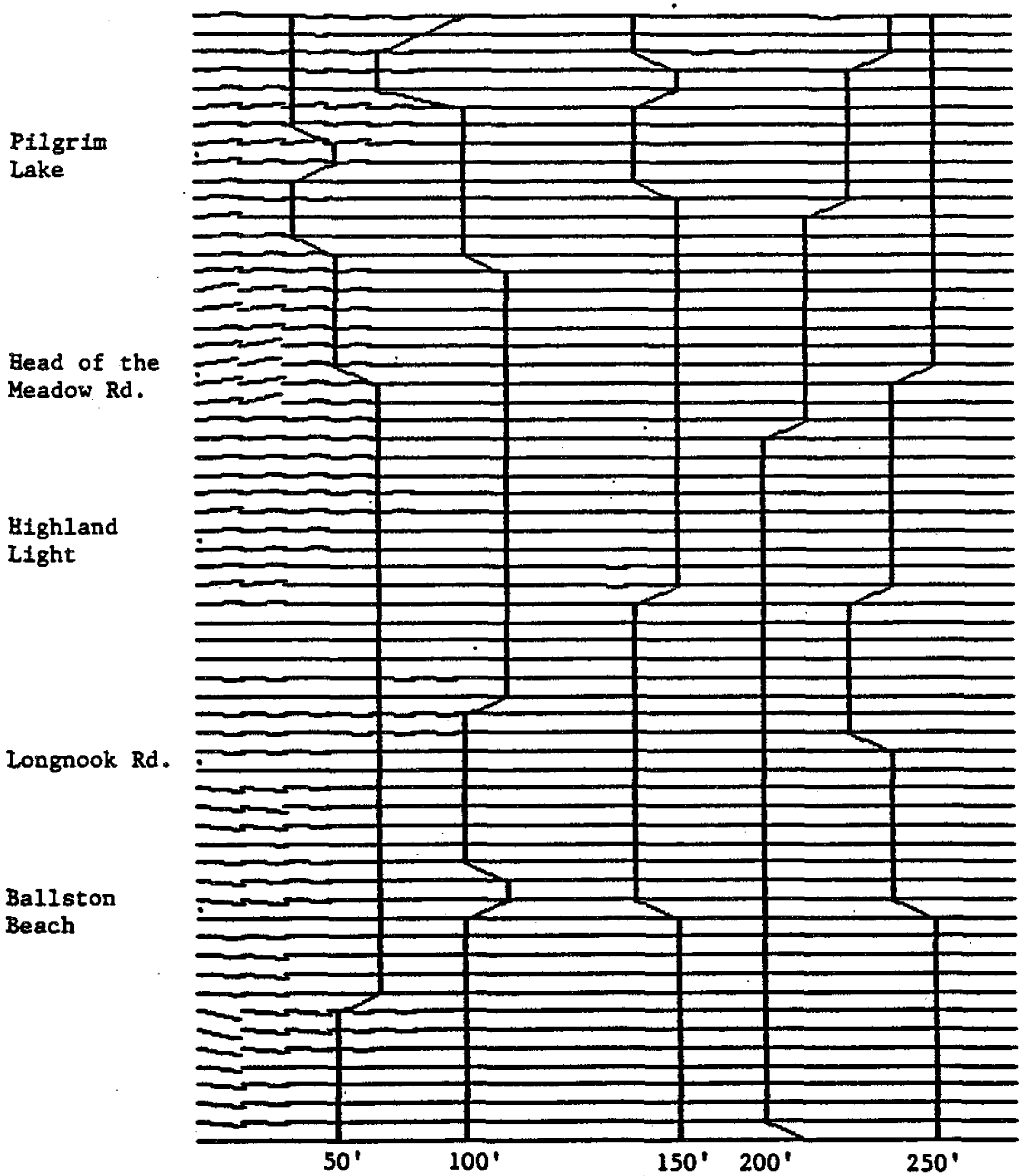
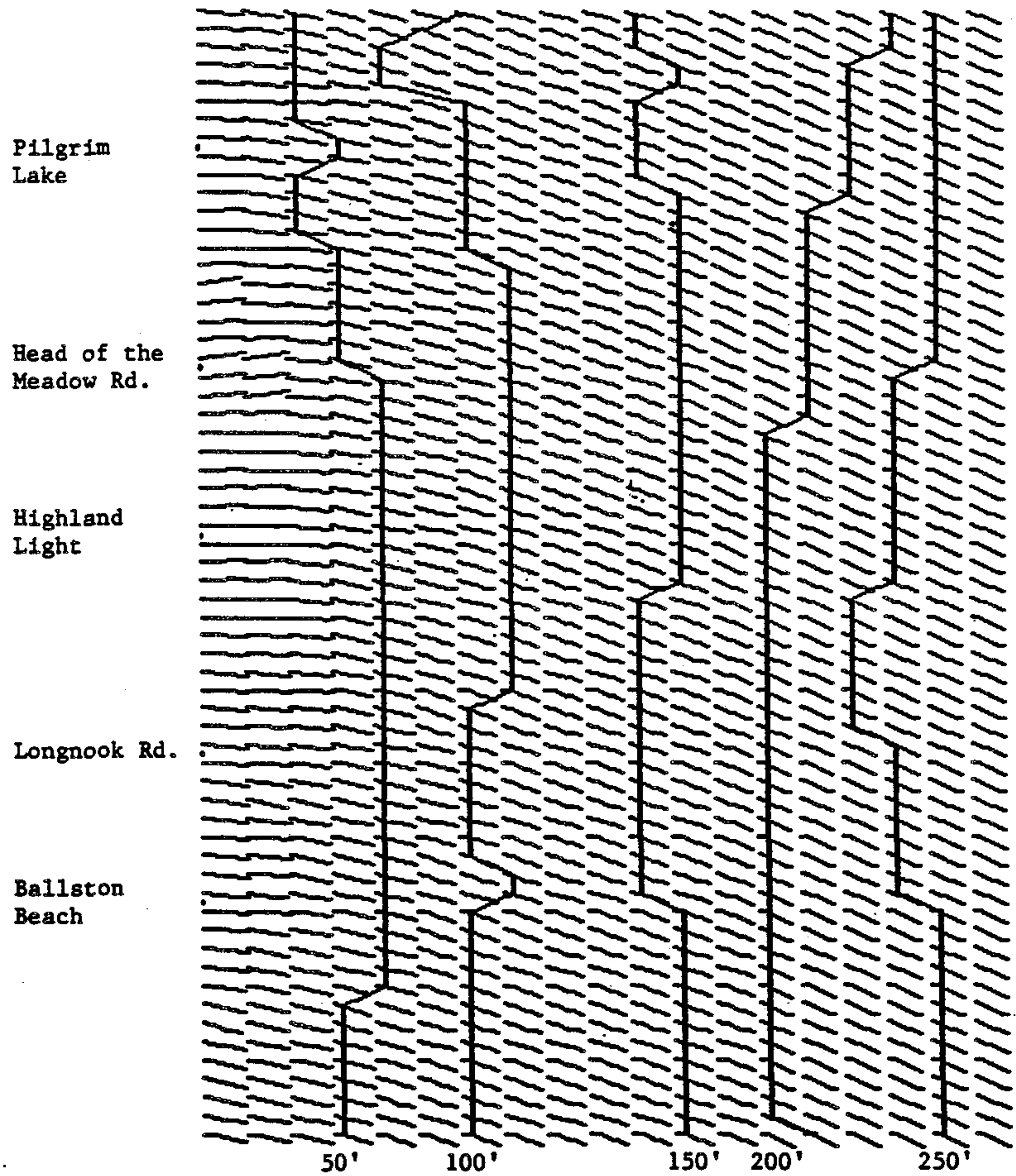


FIGURE 10

Wave Refraction

Waves from the east



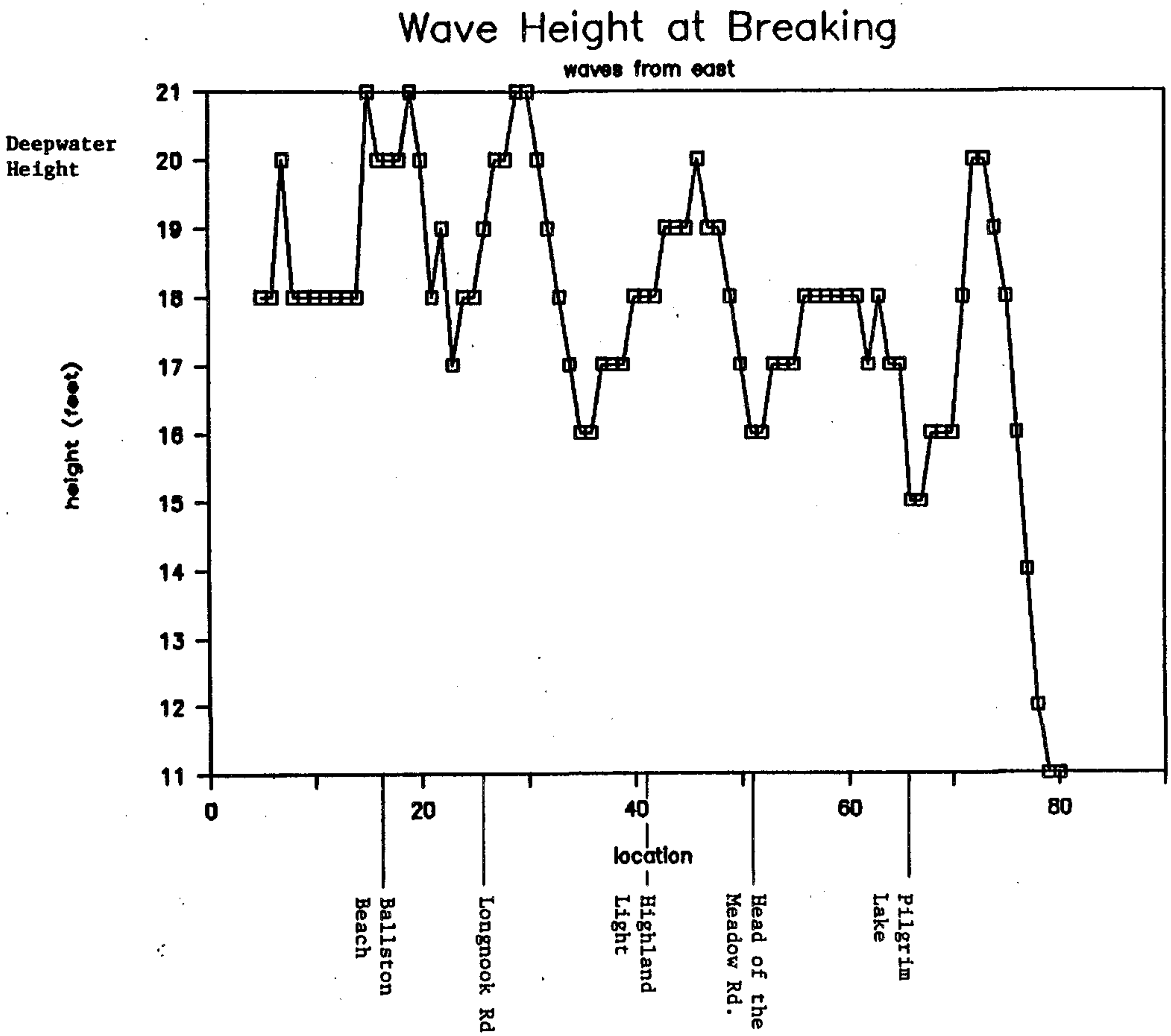

Wave Height at Breaking
waves from east
Deepwater
Height
height (feet)
21
20
19
18
17
16
15
14
13
12
11
0
20
40
60
80
location
Ballston
Beach
Longnook Rd.
Highland
Light
Head of the
Meadow Rd.
Pilgrim
Lake

FIGURE 11

Deepwater
Height

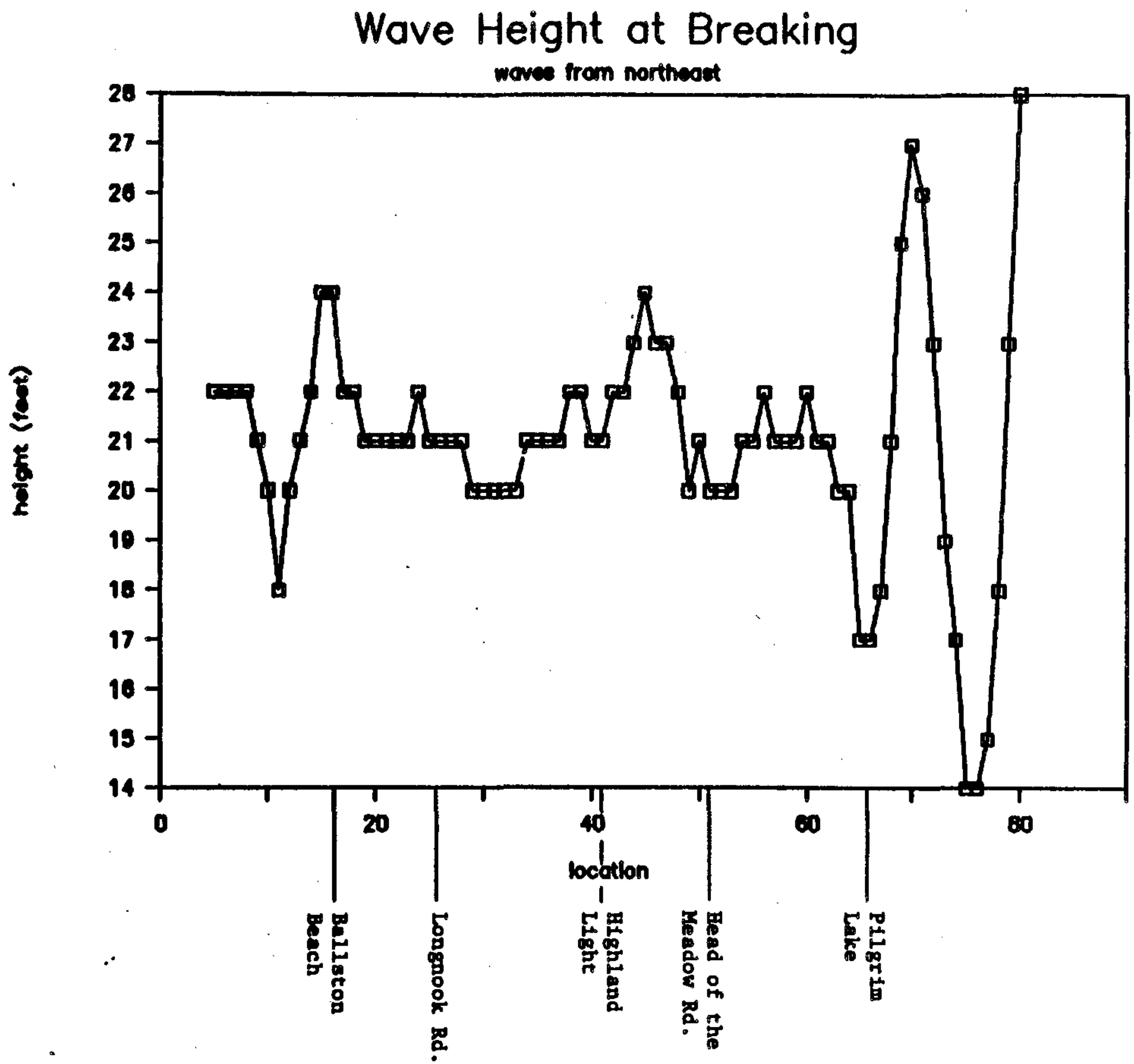


FIGURE 12

Deepwater
Height

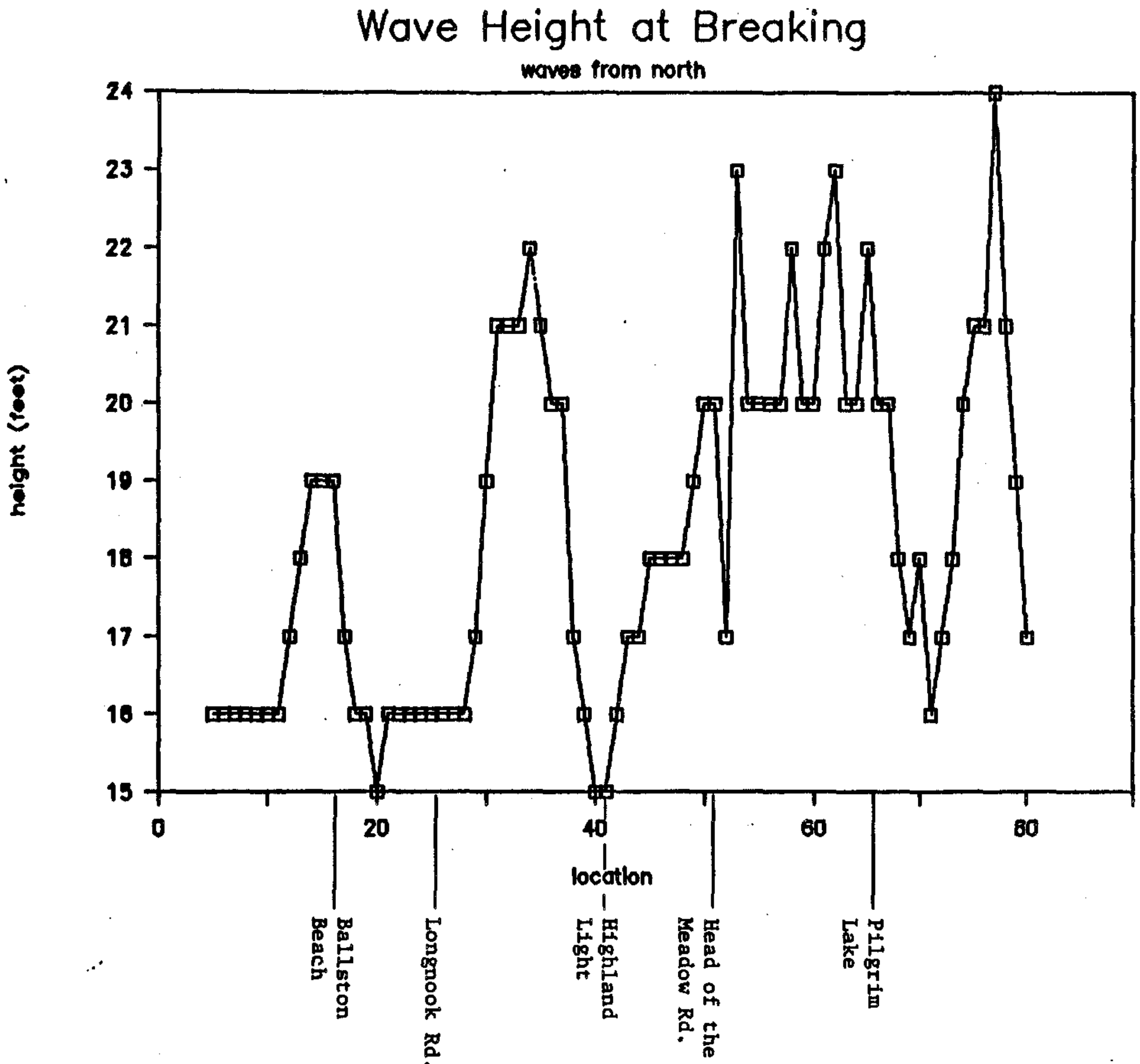


FIGURE 13

In Figures 8 thru 10, the angle the wave makes with the shore at grid points is plotted. This is not a ray trace, it shows wave angle but not areas of energy concentration. These plots were made by a routine written by NED personnel for this study in Turbo Pascal using turtle graphics. Energy concentration is shown in the Figures 11 thru 13. These graphs show wave height at breaking for various locations along the Highland Light Station area.

The bathymetry grid used in this study was oriented in the northeast direction. Waves from the east, northeast, and north were modeled. The wave angle plots show the waves refract around and impact the shore almost perpendicularly. The deviation from perpendicular causes sediment transport. Since most of the sediment is going past Highland Light Station without and major erosion or accretion, no attempt was made to quantify the sediment transport.

When a wave breaks, much of its energy dissipates and the height decreases. The height at breaking is therefore obvious on the RCPWAVE output. A 20 foot wave after shoaling will break in somewhat less than 30 feet of water. The bathymetry in nearshore, shallower water is continually changing and cannot be accurately input to the model. Therefore, the wave height at breaking is the most accurate measure of longshore distribution of wave energy.

The diagram of wave heights from the east (Figure 11) shows Highland Light Station to be in a relatively low wave energy environment. To each side, the waves increase in size. Waves from the northeast (Figure 12) experience less refraction; except north of Pilgrim Lake. It is questionable if results for this area are valid, but since the area is unsuitable for a lighthouse effort was not expended to investigate them. The waves from the northeast were traveling perpendicular to the grid. This could have decreased the calculated refractive effects since error tends to increase the less perpendicular the wave is to the grid. The northern waves (Figure 13) show the most refraction, but again Highland Light Station is in a low wave energy environment. Since the 20 foot wave height was picked arbitrarily, the exact wave heights are not significant. The results give a qualitative description of high and low wave energy locations. Highland Light Station appears to be in a relatively low wave energy location.

A refraction analysis was done in 1976 by Cornillon, Isaji, and Spaulding under contract for the U. S. Army Corps of Engineers NED (Figures 14 thru 16) using a ray tracing routine. While this method does not include diffraction and is probably less accurate than RCPWAVE, the results it obtained are qualitatively similar. To summarize, Highland Light Station is in a good location from a wave energy standpoint.

EROSION PROCESSES AND CRITICAL AREAS

The erosion at Highland Light is caused primarily by water. The water comes in two forms: 1) runoff, which is rain water or ground water, that flows over and through the cliffs, eroding them, and 2) seawater, which impacts the base of the cliffs in the form of broken waves. It is hard to determine which is more destructive because they work together.

WAVE PERIOD: 12.0 SECONDS SWL ABOVE MLW: 7.5 FEET
COMPASS DIRECTION OF WAVE RAY IN DEEP WATER: 180.0 DEGREES

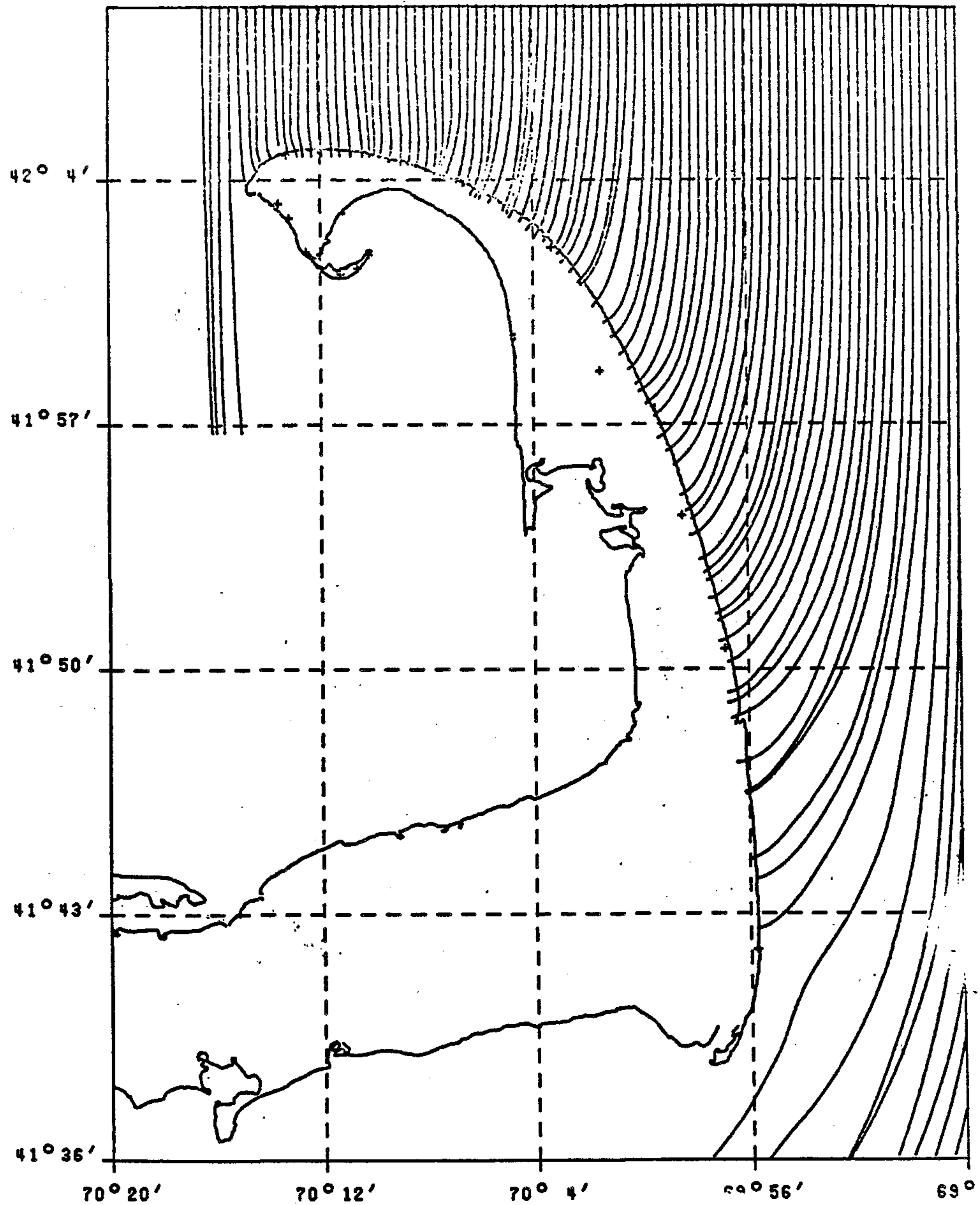


FIGURE 14

WAVE PERIOD: 12.0 SECONDS SWL ABOVE MLW: 7.5 FEET
COMPASS DIRECTION OF WAVE RAY IN DEEP WATER: -135.0 DEGREES

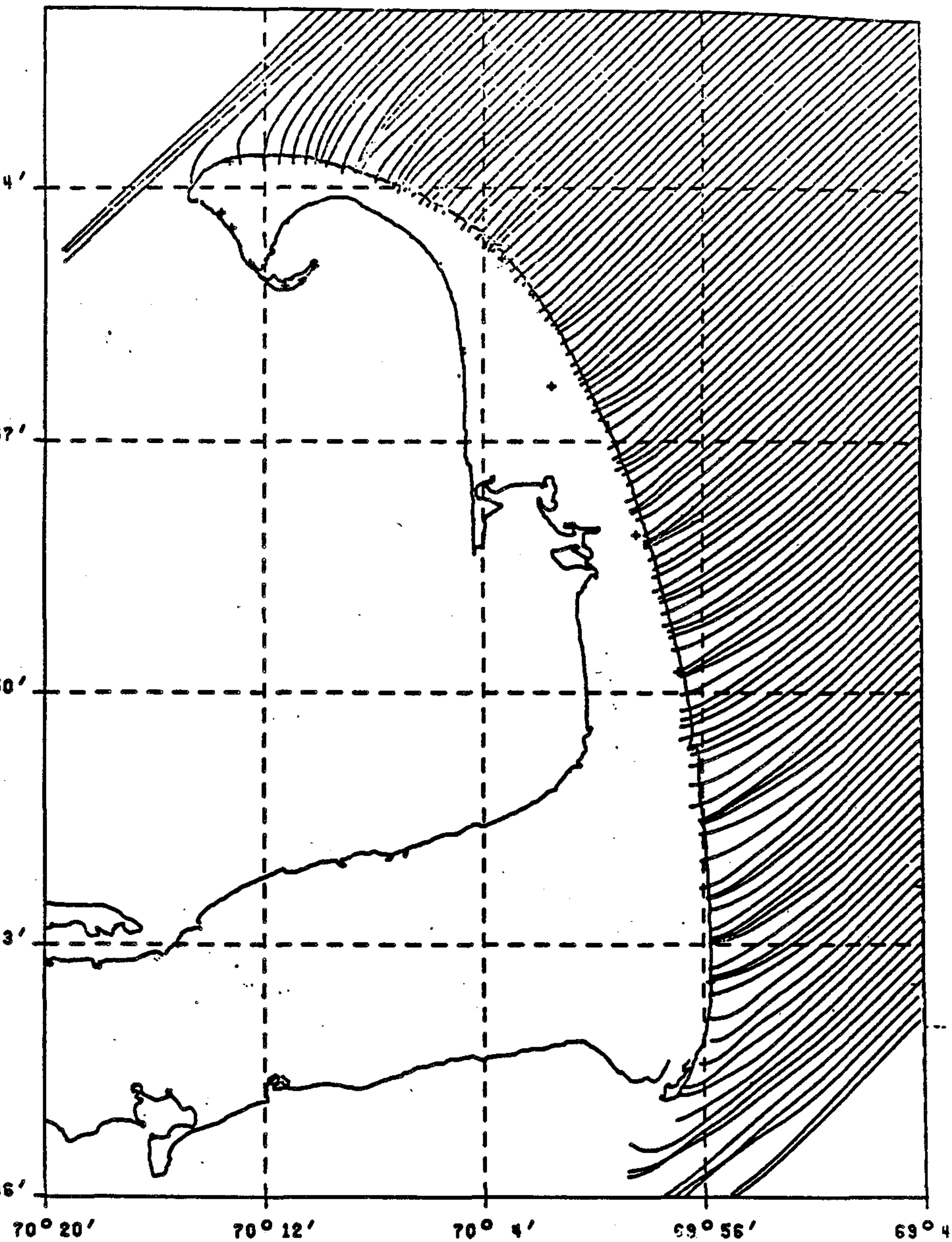


FIGURE 15

WAVE PERIOD: 12.0 SECONDS   SWL ABOVE MLW: 7.5 FEET
COMPASS DIRECTION OF WAVE RAY IN DEEP WATER: -90.0 DEGREES

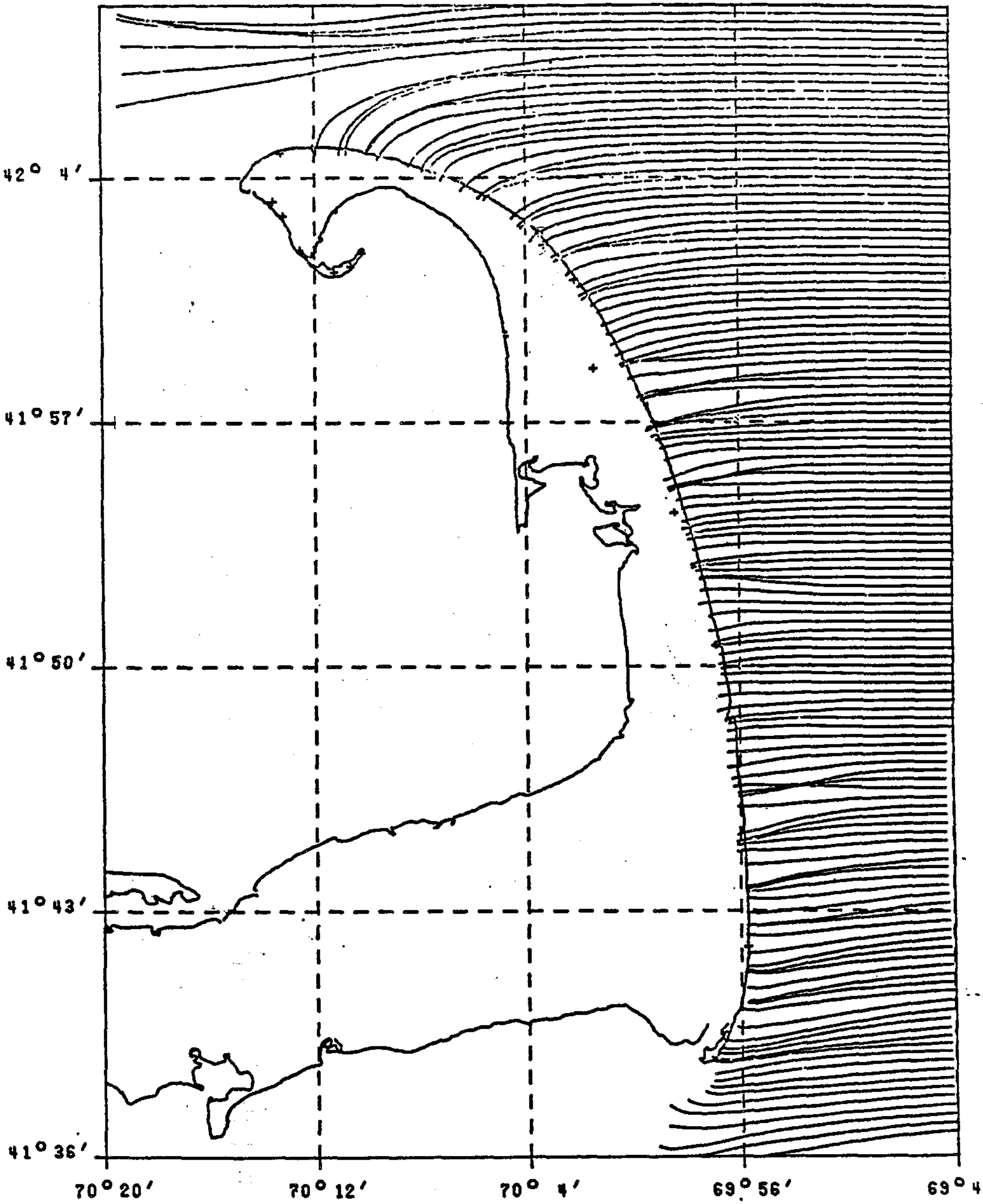


FIGURE 16

PHOTO 1 - RUNOFF (ICE HERE) FLOWING DOWN CLIFF

PHOTO 2 - GULLIES FORMED BY THE RUNOFF

Photo 1 shows the runoff as it runs down the cliff, in this photo, the runoff is seen as ice since the picture was taken on a cold day in January.

On warmer days when the water does not freeze it flows over the cliffs causing gullies as seen in Photo 2. Photo 2 also shows the clear line between the light tan sand above the gray clay. Ground water flowing downward through the sand reaches the impermeable clay. Since the water can not flow through the clay, it flows sideways until reaching the cliff face and then flows over the cliffs forming the gullies. Note how the gullies begin immediately below the boundary between the clay and the sand.

The clay material, eroded from the cliff, flows out onto the beach as shown in Photo 3. The clay is often covered by sand carried onto the beach by waves. The clay which is too fine to stay on the beach during high wave energy storms, is carried away.

Waves break and form bores which attack the cliff bottom. The amount of wave attack is controlled by the width of the beach and other factors; such as offshore bathymetry, slope of the beach, and severity of the storms. Photo 4 was taken looking southward about 1/4 mile south of the lighthouse. Note the wide beach berm which helps protect the cliff bottom. The dark line shows the limit of wave uprush. The cliffs here lie at about 33 degrees which is the angle of repose of sand. They are vegetated which indicates they are probably stable.

Currently, the beach at the base of the cliff in the Highland Light area is very narrow. Photo 5 was taken approximately two hundred yards south of the lighthouse. Note the narrow berm shown by the dark area of wetted sand approaching the cliff base. The cliffs under Highland Light do not support vegetation. They are much less stable than those shown in Photo 4.

Photo 6 shows the indentation in the shoreline in front of Highland Light from a wider perspective.

Waves break and their bores flow up the beach and attack the cliff base as shown in Photo 7. Note the steepness of the scarp, also, the shoe for scale.

When the cliff becomes too steep, it eventually fails in the form of a landslide as shown in Photo 8. This picture was taken at the cliff base directly in front of the lighthouse. The base of the transmitting tower is in the extreme upper right hand corner of the picture. The white chunk of concrete on the upper right hand part of the cliff is the remains of the oil houses which fell over the cliff.

The clay portion of the cliff, being cohesive, does not fail as landslides. It usually falls off as in chunks. The chunk in Photo 9 fell a few hundred yards north of the lighthouse.

Photo 10 shows the effects of the erosion. The concrete slabs are the remains of the oil houses which fell over the bluff. The road too, will soon be lost due to the erosion.

PHOTO 3 - CLAY MATERIAL ERODED FROM CLIFFS DEPOSITED ON BEACH

PHOTO 4 - WIDE BERM PROTECTS CLIFF 1/4 MILE SOUTH OF LIGHTHOUSE

PHOTO 5 - NARROW BERM 200 YARDS SOUTH OF LIGHTHOUSE

PHOTO 6 - INDENTATION IN SHORE AT HIGHLAND LIGHTHOUSE

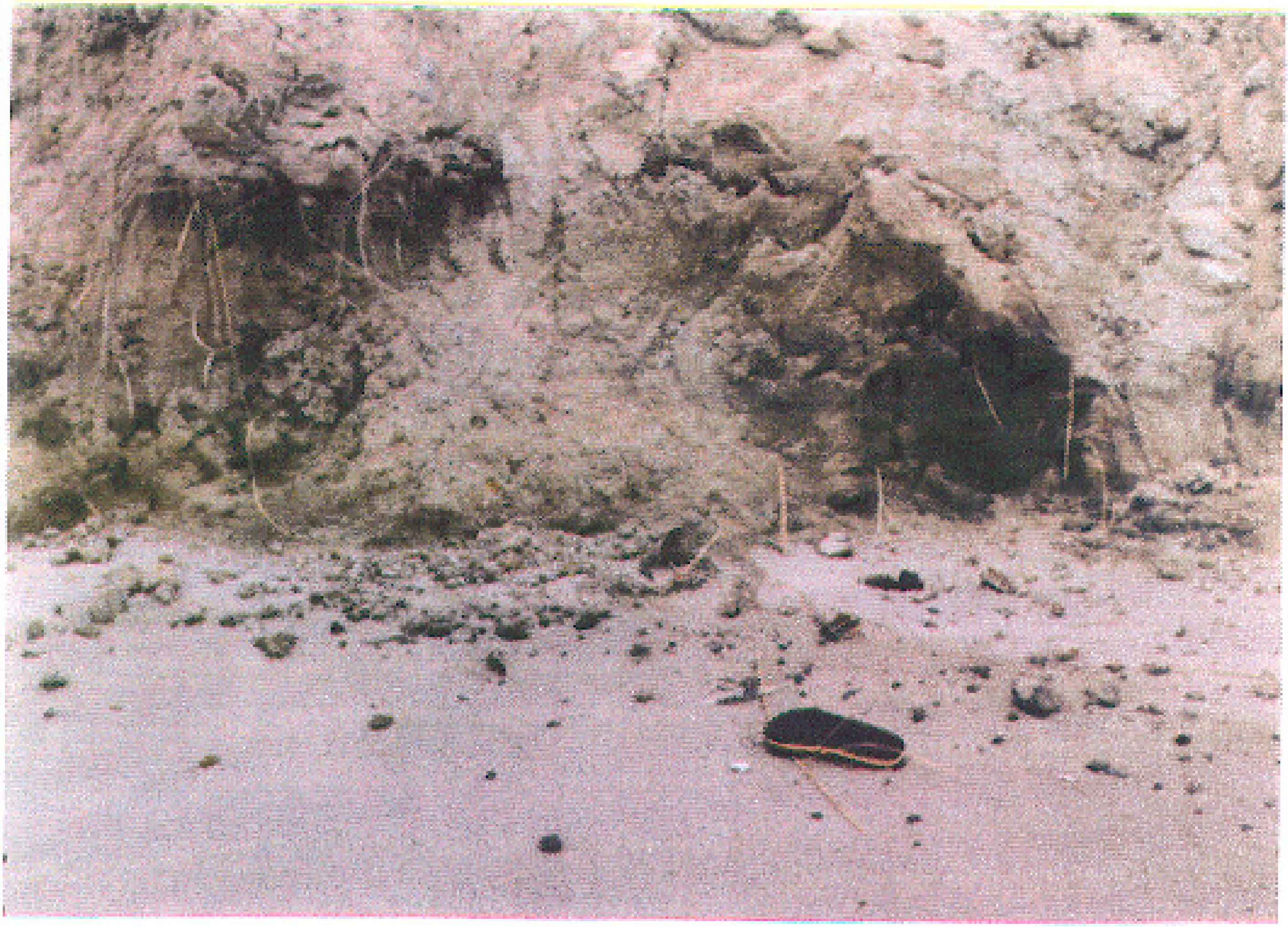


PHOTO 7 - BORES FORMED BY BREAKING WAVES

PHOTO 8 - LANDSLIDE CAUSED BY ERODING CLIFF

PHOTO 9 - CLAY AREA OF CLIFF WHICH FELL OFF AS CHUNK

PHOTO 10- EFFECTS OF THE EROSION

PREDICTING FUTURE CONDITIONS

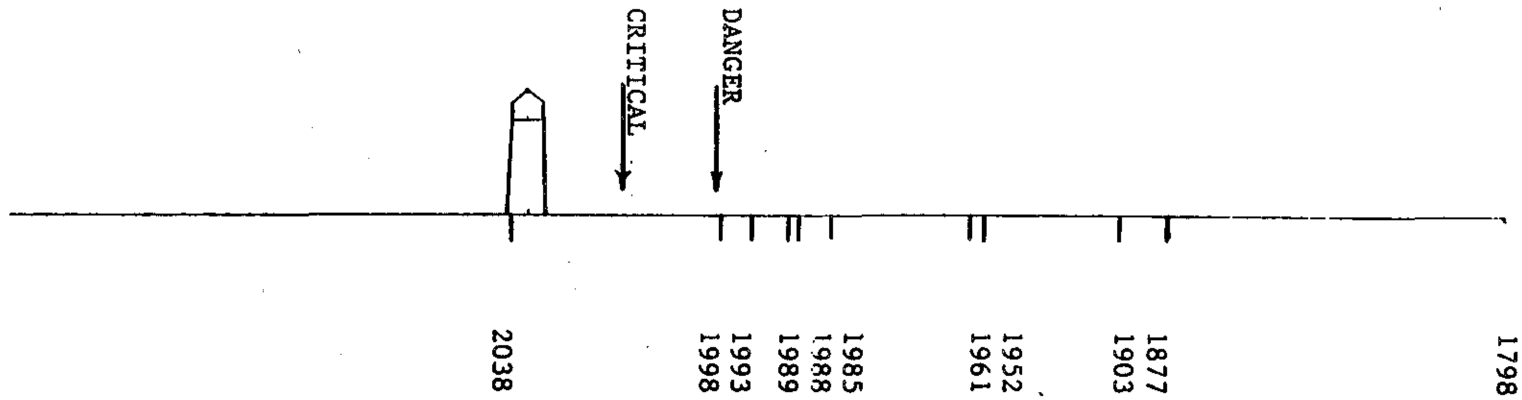
On January 22, 1988, the center of the lighthouse structure was 143 feet from the bluff at its closest point. Since the structure weighs over 400 tons, it will not stand very close to the bluff edge without the bluff failing. Allowing that the average rate of erosion over the last 190 years has been 1.9 feet per year one could say that the lighthouse will topple into the ocean in approximately 75 years. This is obviously an unrealistic assumption since the erosion rate is variable. Based on the reports of Gatto and the USCG monitoring program, it appears to be accelerating recently. Gatto found it to be 15 feet per year between 1971 and 1974. Using this, value the life expectancy of Highland Light Station decreases to 8 years. The real expectancy is most likely between these two values. Therefore, it estimated that the lighthouse will be in imminent danger of falling when it is 50 feet from the bluff edge.

Bank erosion is based on many factors. Theoretical methods have not developed to the point where they can accurately predict erosion. Although storm intensities can be predicted, the amount of erosion caused by a storm cannot be accurately predicted. The erosion rate depends upon the number and severity of storms, how much erosion these storms cause, and the geotechnical properties of the cliff face as it erodes. Therefore the predictions will be based on historical changes.

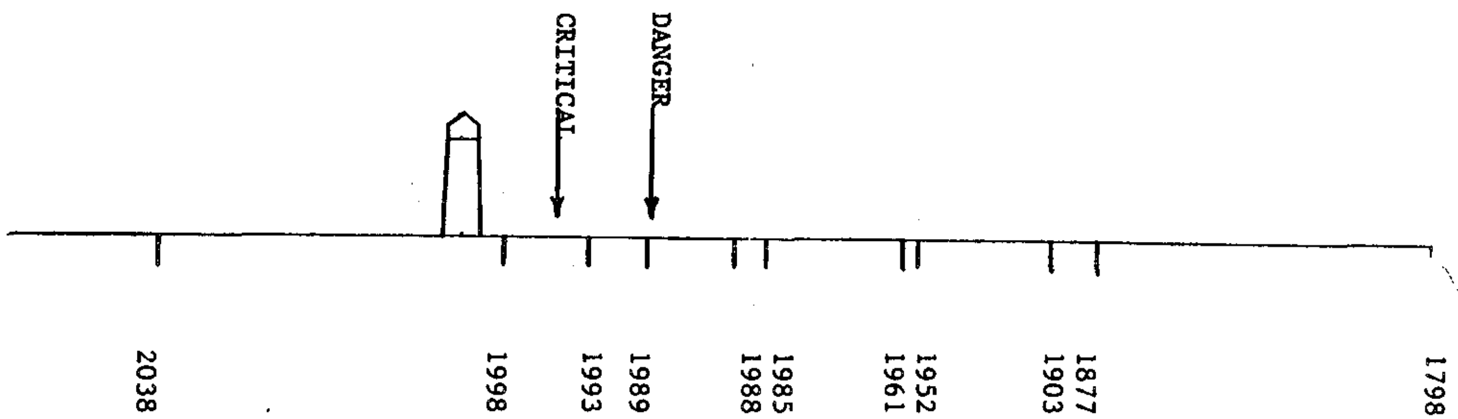
Two scenarios will be presented: the "most likely" which is the best guess as to what will happen and the "worst case" which is the worst that is likely to occur. The position of the bluff in 1, 5, 10 and 50 years will be predicted for each scenario. (See Figure 17.)

From 1982 to 1986 the bluff retreated 20 feet, therefore it is estimated that the bluff will continue to erode at a rate of 5 feet per year next year and for the following 5 years. There are no obvious signs of imminent major failure of the bank. Highland Light is currently experiencing higher than average erosion. Since the average erosion over the last 190 years has been 1.9 feet per year the erosion rate over the next 50 years should decrease towards this value. The erosion rate over the next 10 years is predicted to decrease to an average of 4 feet per year. Since 1952 the bank has eroded at an average rate of 2.6 feet per year. By averaging, the erosion rate over the next 50 years comes to 3 feet per year.

Estimating the worst possible case is a bit more difficult. Obviously, the worst possible case is for the lighthouse to fall in the water today. This is possible but highly unlikely. The cliff in front of the lighthouse is 130 feet high and lies at an angle of about 40 degrees. If this reduces to the angle of repose of sand which is 33 degrees, 45 feet of bank would be lost. Remembering Thoreau's value of 40 feet lost in one season, the 1 year worst case is 45 feet. Gatto reported 15 feet per year of erosion for 3 years. He also states that some values in this area are suspect, but there were some high erosion rates reported over the years, therefore, we are assuming the "worst case" erosion over 5 years is 15 feet per year; over 10 years it is 12 feet per year; over 50 years it is 6 feet per year. These 10 and 50 year estimates are 3 and 2 times the most likely estimates respectively. Over time the worst case and most likely case estimates should approach each other since the variability of erosion rate becomes less of a factor.



MOST LIKELY CASE



WORST CASE

FIGURE 17 - PREDICTED CLIFF EDGE POSITIONS

PLAN FORMULATION AND EVALUATION

From our findings, it becomes apparent that the erosion of the cliff area will soon endanger the lighthouse structure. Several alternatives have been investigated in order to determine the best solution to the problem. The alternatives were analyzed based on cost estimates, ease of implementation, and environmental considerations. Cost estimates of the alternatives, as well as supporting documents, may be found in Appendix 2, Cost Estimates and Supplemental Information.

Preserving the lighthouse can be accomplished by one of three methods: namely, stopping the erosion of the cliff base; making the cliff stable; and, moving the lighthouse away from the cliff.

The alternatives investigated to stop the erosion of the cliff base included placing sandfill along the beach area at the base of the cliff to stabilize the beach and the cliff area; constructing a series of groins at the base of the cliff to keep the beach from eroding and prevent the undermining of the cliff; use a combination of sandfill and groins; constructing rock revetment in combination with upper bank stabilization; and, constructing an offshore breakwater or using artificial seaweed to reduce the wave climate in the area. Some of these methods were investigated by the Corps for the Cape Cod Easterly Shore Beach Erosion Study, published by the New England Division of the Corps in 1979. The Easterly Shore study looked at protecting approximately 20 miles of shoreline from Truro to Nauset Light. It found protection measures to be economically unjustified and therefore did not look at environmental impacts or detailed designs. Some of the designs presented herein were drawn from that study.

Sandfill is sand placed on the beach to form a wider berm so the storm waves break further offshore and do not impact the cliff base. Reasonable fill dimensions are approximately 550 feet long by 100 feet wide with a berm elevation of 16 feet above mlw. The problem with this alternative is waves will eventually carry away the sandfill as they do now at the cliff base. Generally, the more successful nourishment programs like these have involved relatively long fills since the erosion rate is fastest at the fill ends. Since it is desired to keep sandfill in front of the lighthouse, periodic nourishment would be required. This would be the largest cost involved with this alternative. Renourishment requirements were calculated assuming that the sandfill will behave as described by Inman's model for short fills. A short length of protruding sandfill tends to move in the downdrift direction as a whole unit which slowly flattens out. The model is based on a diffusion - advection equation. The partial differential equation was numerically solved, using the explicit method, by a computer program written by NED personnel. From these calculations, it was determined that the beach would have to be renourished every 3 months. While this value seems high, it shows that maintaining a sandfill project in the Highland area is not only costly but probably not feasible.

Groins are rock structures which protrude out into the ocean and trap the sand being transported in the longshore direction. A sand fillet will form on the updrift side of the groin. The downdrift side will be starved for sand and erosion in this area will accelerate. This will cause an indention in the cliff line which could flank the groin. In time, the erosion could go behind the groin and isolate an island of rock which would become ineffective and could form a hazard to navigation. However, a groin could protect the lighthouse for possibly the next 30 years, although the rock would probably be there forever. The groin would result in a visual impact on the rugged character of the beach in an area where there are currently no man-made structures.

Groins can be used to stabilize placed fill. This alternative would help to partially solve the periodic nourishment problem associated with the sandfill option mentioned earlier. However, nourishment requirements would still be high since groins are often estimated to only reduce nourishment requirements by about one half. Furthermore, the erosion downdrift of the groins problem would still exist.

Rock placed in a manner to armor the cliff base is called revetment. The revetment would most likely have to be constructed in combination with some form of bank stabilization at the top of the cliff. It would be impractical to revet the entire cliff face; the construction costs would be high. The bank stabilization at the top of the cliff could include vegetation along with drainage plans to keep the runoff away from the cliff's edge. Revetment will stop the erosion of the cliff behind it. However, erosion will likely continue at the structure's toe and eventually the revetment will be undermined and fail. The comparison of alternative plans to protect Highland Light presented below in Table 3 indicates that even if the 800 feet long revetment were to have an economic life of 50 years, which is unlikely in the high energy environment at Highland Light, it is not the most economically feasible alternative considered. Further, only a limited distance of cliff can be protected, causing the area adjacent to the revetment to erode and the revetment itself to unravel. This would be a particular problem on the downdrift end of the structure.

A detailed plan of a revetment suitable for the protection of Highland Light is beyond the scope of this report. For illustrative purposes, however, a typical cross section of a revetment is seen in figure 17-A. An analysis of the situation, suitable for general planning purposes only, supplies the following design data.

a) deep water wave height (from SEAS data) of 20 feet

b) estimated vertical run-up on rough quarry stone of 16 feet

c) revetment slope of 1.0 V on 1.5 H

d) armor layer thickness of 15 feet
underlayer thickness of 2 feet
bedding layer thickness of 1 foot

e) cross section of structure is 850 square feet

f) linear dimension of 800 feet (length of lighthouse property)

g) volume of revetment using above dimensions is 680,000 ft^3. Assuming 25% voids and a rock density of 165 lbs/ft^3 results in a weight of 45,000 tons

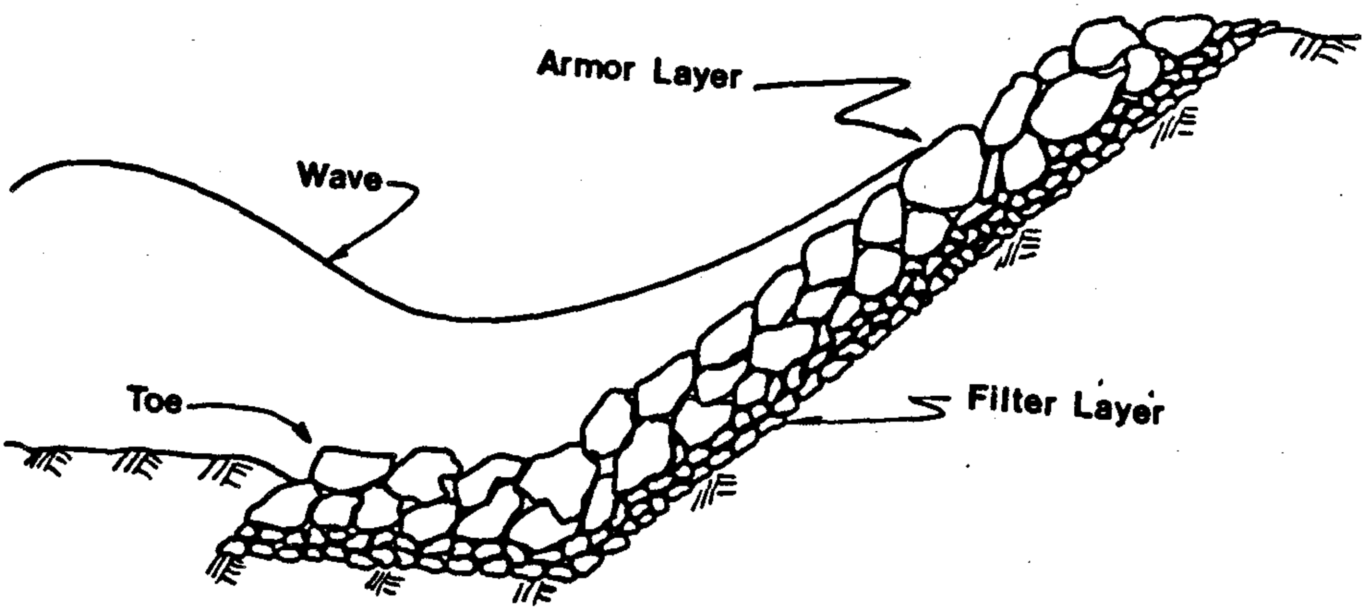


FIGURE 17-A TYPICAL REVETMENT SECTION

Gabions have been used in the coastal environment as a form of low cost shore protection. Gabions are rectangular steel wire baskets that are filled with stones. They have a variety of applications such as retaining walls and revetments. Gabions could be used with filter fabric and stone toe protection in an attempt to armor a cliff such as Highland Light. However, the Corps Coastal Engineering Research Center does not recommend their use in high energy environments such as found near Highland Light because of the flexing and wire fatigue and failure that commonly occurs. Additionally, gabions are not recommended in active surf zones where sand and debris provide an abrasive environment which can cause wear and eventual failure of the PVC coating of the wire baskets.

Concrete filled fabric forms were also not seriously considered in this report. There is no evidence to suggest that such structures would withstand direct wave action or would offer substantial toe protection.

Breakwaters, as the name implies, are rock structures built offshore to break the waves. They would reduce the size of the waves impacting the cliff base by causing them to break offshore. In addition, like groins, they interrupt longshore transport. Longshore transport is caused by the energy of waves which strike the shore obliquely. If the waves are interrupted over a section of beach, the lack of wave energy will cause the sand normally transported past the section of beach to be deposited. If the breakwater is too close to the shore, a tombolo will form connecting the breakwater to the shore. This will react the same as a groin and cut off longshore transport and cause downdrift erosion. The breakwater must be constructed far enough offshore to allow waves to diffract around it, thereby allowing enough sand to pass between the breakwater and the beach preventing downdrift starvation. This option requires considerable coastal design work. The offshore breakwater could be a hazard to navigation. Although most of the structure would be below MHW, some people might find it visually objectionable.

Artificial seaweed is strips of cloth-type material suspended offshore to foster sand accretion. In high energy areas such as Highland Light, however, the Coastal Engineering Research Center, CERC, does not recommend artificial seaweed for the prevention or attenuation of erosion.

Slope stabilization measures allow the cliff to maintain a steeper angle. However if the base continues to erode, there is a limit as to how long steep soil can hold without eventually failing. These measures could buy time for the lighthouse to be moved or could be combined with erosion control measures along the bottom. Slope stabilization measures investigated include vegetation and dewatering.

Vegetation of the cliff area should make the bank more stable and slow the erosion process. The reason for the variable distribution of existing vegetation is unclear. Possibly the soil conditions in front of the lighthouse are such that vegetation will not hold, or perhaps runoff over the bank undermines the cliff face, or the steepness and instability of the cliff face make it difficult for vegetation to root and survive. Extensive horticultural and hydrologic studies would be needed to determine the cause of the problem. Vegetation, if it could be maintained, would help to stabilize the bank area, but it will not completely stop the erosion.

Other areas of the country have been stabilized using a combination of structural and vegetative slope protection. These structural measures include terracing the slope, reveting the base and stabilizing the bank enough to allow the vegetation to root so that its chances of survival would be greatly increased.

In areas with clay strata, ground water is often a cause of erosion. Water seeps into the ground until it hits an impermeable layer of clay and then runs sideways. It exerts pore pressure on the cliff face, pushing it outwards. By flowing between the soil layers it also lubricates the interface between layers. This allows one layer to slide over another, when pushed by pore pressure and gravity, and eventually fall. When the water flowing between the layers reaches the cliff face, it flows down the face carrying clay along with it.

There are various ways to dewater the soil and solve these problems. One is to drill wells along the top of the cliff and pump the water out. Another is to drill down through the impermeable layers allowing water to flow down through the drilled holes instead of flowing sideways and down the cliff. A third method of dewatering is to drill a pipe into the side of the cliff and allow the water to flow out through pipes instead of out through the layers.

Any formal plan of dewatering is dependent on the position and seasonal variation thereof of the water table, the amount of water removed, the stratigraphy of the area and the porosity and permeability of the sediments. Most of these variables were not determined in this study and therefore no detailed plan was formulated. Additionally, costs of dewatering may be prohibitive. The U.S. Army Corps of Engineers, in a 1973 report, quoted a dewatering estimate for a similar site at Gay Head on Martha's Vineyard which ranged from $1,800,000 to $2,200,000 in 1970 dollars.

Provisions should be made to protect the lighthouse before it is in danger of being destroyed. It could be very valuable to know when the lighthouse is likely to fall. While it may be possible to calculate this, a better move would be to actually go out and measure what the slope is doing.

Before failure, a given slope will usually start slipping, with the rate of slippage varying with the time of year, ground water level and many other factors. Closer to the time of failure, the rate of slippage will tend to accelerate. To predict slope failure is to measure the acceleration, or how fast the rate of slippage is increasing. This can be done with a borehole extensometer which consists of a long metal rod in a borehole. One end of the rod is anchored in the sand far enough away from the slip surface that it does not move. The movement of the surface is measured in relation to the fixed rod. Displacements of 1/1000 of an inch can be measured.

Using these instruments it is possible to predict failures two years in advance. The essence of this method is to measure accelerations but instrumentation placed just when a crises appears imminent may not do much good. Instrumentation placed at this time will record the current rate of slippage but when there is no previous rate of erosion known with which to compare the current rate, the rate of acceleration is unknown. The fact that the slippage may accelerate, decelerate or even reverse over the course of the of a year complicates this problem. Much of this occurs with seasonal fluctuations in the ground water level.

In January 1988 the center of Highland Light was 143 feet from the cliff edge at its closest point. Since the lighthouse is not in imminent danger, the Monitoring Survey Program described in Appendix 1 could be supplemented with measurements of bank slippage in order to give early warning of critical danger to the lighthouse when it is 50 feet from the cliff. The Coast Guard would thereby be better prepared to take appropriate action. Placement of the lighthouse further away from the cliff edge can be done by moving the existing one or building a new one far enough back.

Moving the lighthouse at first appears to be an unlikely solution. It is estimated to weigh between 400 and 500 tons. However, there are a number of contractors who do such work. The Move the Lighthouse Committee in North Carolina has investigated the possibilities of moving Hatteras Light. Hatteras Light is 208 feet tall and weighs approximately 2,600 tons. This is about 5 times the size of Highland Light. Appendix 2 carries a letter from the International Association of Structural Movers stating that there are several contractors in the country capable of moving the Hatteras Light. Although to our knowledge no large masonry lighthouses have been moved, many large buildings have been moved including 7 story office buildings, city blocks, airport control towers and water tanks.

After the structural integrity of the lighthouse is investigated and any repairs made, the moving process could begin. Holes would be drilled in the base of the lighthouse and beams placed through them. The beams ride on wheels which ride on tracks similar to railroad tracks. The largest part of the job is building the tracks. Movement consists of rolling the lighthouse along the tracks.

The last alternative is to abandon the lighthouse and build a new one. It would be best to dismantle the old lighthouse otherwise it could create potentially dangerous rubble at the bottom of the cliff when it falls over. It would also mean losing a structure which has served its purpose well since 1797. The new lighthouse could be identical in structure, possibly using the same material as the old structure, or it could be more modern.

SUMMARY AND CONCLUSIONS

Highland Light Station is an important aid to navigation, therefore it is important that we allow a generous margin of safety. There is no need to discuss the erosion problem when the threat of the lighthouse being in pieces at the bottom of the cliff is imminent. If the cliff is close to the structure the stresses imposed on the earth by the structure itself could increase the erosion rate.

Remembering Thoreau's one season erosion value of 40 feet, it seems that when the structure is within 50 feet of the bluff, it should be considered as being in imminent danger. Since any plan to move or reconstruct the lighthouse will take several years to accomplish, it would best to get started when the bluff is about 100 feet from the lighthouse.

At this time, it appears that the monitoring survey program discussed throughout this report, and in detail in Appendix 1, has been discontinued. This program should be reinstituted in order to allow the Coast Guard to have sufficient warning of the possible loss of the Highland Light Station.

Alternatives discussed in this report could provide some protection to the structure and so prolong its life. The alternatives cover a wide range of possibilities, from the non-structural vegetation of the bank to the moving of the entire structure further inland. The alternatives also have problems associated with them. The bank area does not appear to be able to hold vegetation as well as the adjoining properties, and a maintenance program for the vegetation may prove difficult and impossible. Moving the structure has the obvious problems of cost and engineering means. There are a number of considerations to be analyzed in the selection of a new site. It would not appear to be practical to move the structure to a location further up or down the immediate shoreline, since the wave analysis shows the present location to be in the lowest energy concentration areas along the shoreline. Much of the discussion in this report supports the conclusion that the structure should be moved further inland. This would allow for more time in the life of the structure.

Table 3 presents a comparative listing of the ten alternatives for protecting Highland Lighthouse. The survey monitoring program that had been undertaken by the Coast Guard should be reinstituted in order to monitor the rate of bank erosion and to provide adequate time to undertake a course of action. This survey system could be supplemented by incorporating measures to track slippage along the slope. (See pages A2-6 and A2-7.) In addition, the Coast Guard could investigate the feasibility of stabilizing the slope structurally and with vegetation. Erosion would, however, not be stopped with these measures, but the life of the lighthouse at its present location could be prolonged.

Alternatives 9 and 10 (relocation and construction a new structure) are technically and economically feasible plans to address the erosion problem. More detailed analyses, including design and cost estimates, would determine whether relocation or the constructing of a new lighthouse is the optimal solution.

RECOMMENDATIONS

It is recommended that the Coast Guard take the necessary steps to either relocate the lighthouse or demolish it and reconstruct a new lighthouse based on the optimal technically, economically and environmentally feasible and publicly acceptable solution to the erosion problem at Highland Lighthouse.

It is further recommended that the Coast Guard reinstitute the survey program to monitor the evolution of the erosion at the light station. Appendix 1 provides details on ways to update and improve the original survey program. The survey monitoring program will track the rate of bank erosion in order to have adequate time to undertake the selected plan.

Concurrent with the reestablishment of the survey program, studies could be initiated to determine if methods of vegetation and structural bank stabilization are feasible in order to prolong the life of Highland Lighthouse in its present location.

TABLE 3
COMPARISON OF ALTERNATIVE PLANS TO PROTECT HIGHLAND LIGHT

ALTERNATIVE Number	ALTERNATIVE Description	COSTS First Costs	COSTS Net Present Value of Costs over 50 Years at 10 Percent	COMMENTS
1	Measuring bank slippage for early warning.	N/A	N/A	Could supplement survey monitoring described in Appendix 1.
2	Vegetation with Structural slope stabilization	N/A	N/A	A number of methods are available - investigation is needed. Sucess depends highly on maintenance.
3	Sandfill - base of cliff	$ 620,000	$2,280,000	The entire amount of sandfill would have to be replaced 4 times a year.
4	Groins - base of cliff	$ 830,000	$ 900,000	Areas downdrift of groins may undergo accelerated erosion as result of groins. Plan not technically feasible
5	Sandfill with groins	$1,400,000	$9,420,000	Areas downdrift of groins may undergo erosion. Plan not technically feasible.
6	Revetment - cliff base	$3,000,000	$3,690,000	Erosion of areas adjacent to revetment may cause revetment to unravel. Plan not technically feasible.
7	Offshore Breakwater	$3,900,000	$4,640,000	Requires considerable Coastal Engineering Design work. May not be environmently acceptable.
8	Artificial Seaweed	N/A	N/A	Plan not technically feasible.
9	Relocate Structure	$ 800,000	$ 880,000	Detailed design and cost estimates and analysis required to determine which of these two plans is more cost effective.
10	Construct New Structure	$1,800,000	$1,850,000	

APPENDIX 1

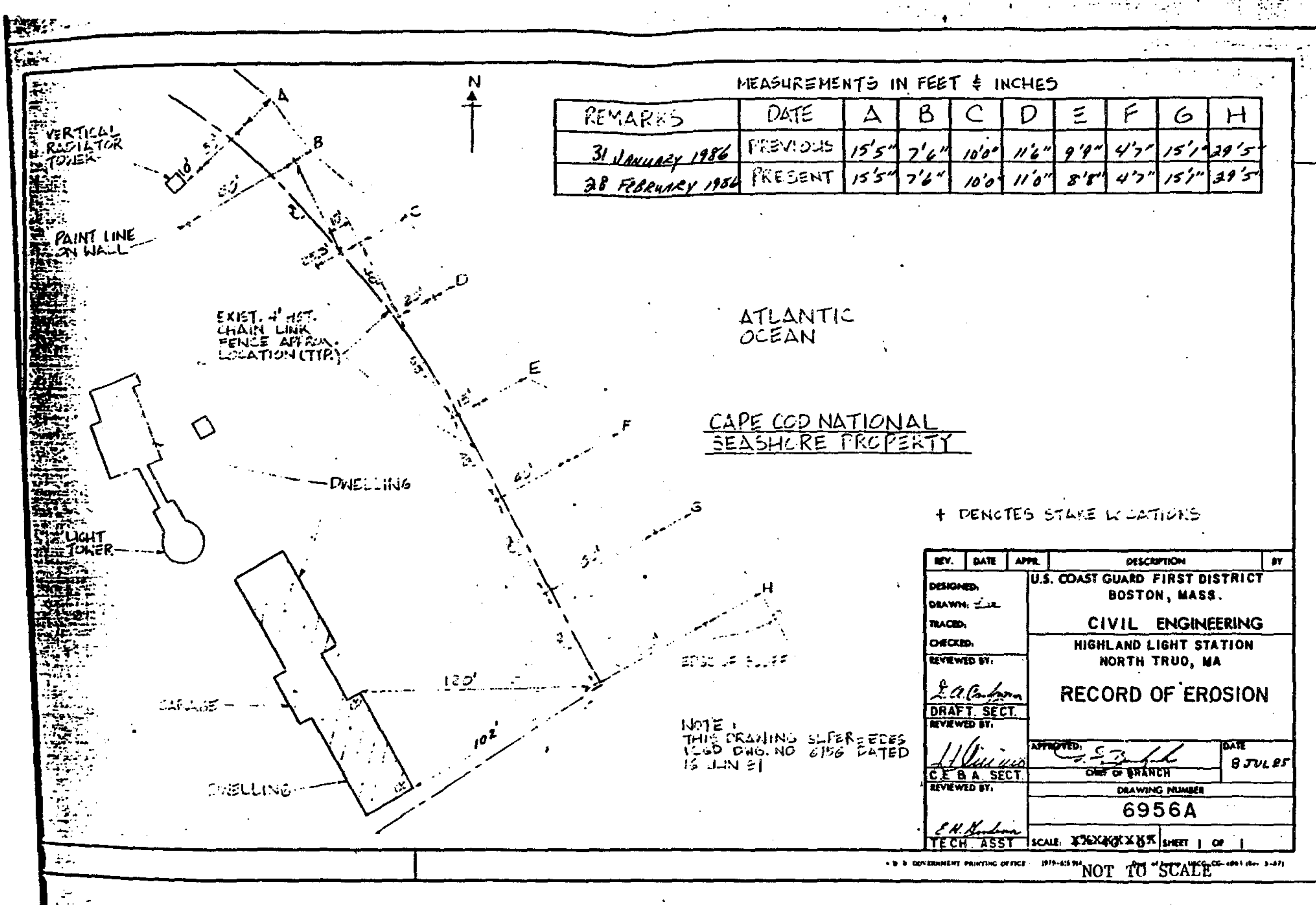
MONITORING SURVEY PROGRAM

MONITORING SURVEY PROGRAM

The Coast Guard has maintained an erosion record at Highland Light Station for a number of years. About a dozen stakes were placed at approximately 50 foot setbacks from the bluff and the distances from the stakes to the bluff was measured every month. The data was recorded on plates drawn by the Coast Guard. A sample is included as Figure 18. The form was revised every few years. Blank forms dating back to 1959 were found in the Coast Guard files, however, the completed forms from before 1982 could not be located. In Figure 19, the March 1982 and March 1986 data is plotted as a shoreline change map. All of the available data is included in tabular form as Table 4 and in graphical form as plots of erosion versus time in Figures 20 thru 27. Figure 28 shows the cliff edge position at each of the USCG monitoring stations for 1982 and 1987. Figure 29 is a plot of the average rate of erosion at each of the stations for the years 1982 thru 1987. An analysis of this survey information clearly shows that the erosion is not continuous but occurs irregularly as chunks fall down the cliff. The erosion rate appears to vary from about 5 feet per year to about 1 foot per year, depending on when large chunks fall at a given spot. At station F, for example, a 16 foot chunk of cliff fell off in October 1985.

The monitoring survey program, which was performed by the Coast Guard at at Highland Light Station, consists of monthly measurements from control stakes to the cliff edge. The control stakes are placed back from the cliff edge and in some instances have had to be moved when the cliff erosion came to close to the location. From the maps which we have been supplied by the Coast Guard, it appears that this program has been being performed since 1959, however, it is not clear that the program became monthly until after 1982. During research of the Coast Guard files, it was found that the survey maps prior to 1982 were missing. There is a question at this time as to whether or not this monitoring program is still being conducted at the lighthouse. If this program has been discontinued, it is very important that this or a similar program be reinstituted in order to give the Coast Guard adequate warning of the failure of the bank.

The monitoring program being performed at this light station is very comprehensive and there appears to be only one possible recommendation toward improving the process. A question arose during the analysis of the survey information as to how well the stake locations are tied into any semipermanent structure farther from the edge of the cliff area. There appears to be one measurement taken from the lighthouse structure to the southern most stake, however, there do not appear to be any other ties available to other stakes. The recommendation would be to tie the entire survey program in to the property bounds at the back of the Coast Guard property. A baseline should be set up using the property bounds, and then the erosion survey stakes should be tied into this baseline. If any of these stakes are lost or moved, the new stakes would be able to be replaced and there would be no need for a gap in the historical information for that area.



REMARKS	DATE	A	B	C	D	E	F	G	H
31 JANUARY 1986	PREVIOUS	15'5"	7'6"	10'0"	11'6"	9'9"	4'7"	15'1"	29'5"
28 FEBRUARY 1986	PRESENT	15'5"	7'6"	10'0"	11'0"	8'8"	4'7"	15'1"	29'5"

FIGURE 18 - SAMPLE COAST GUARD SURVEY PLATE

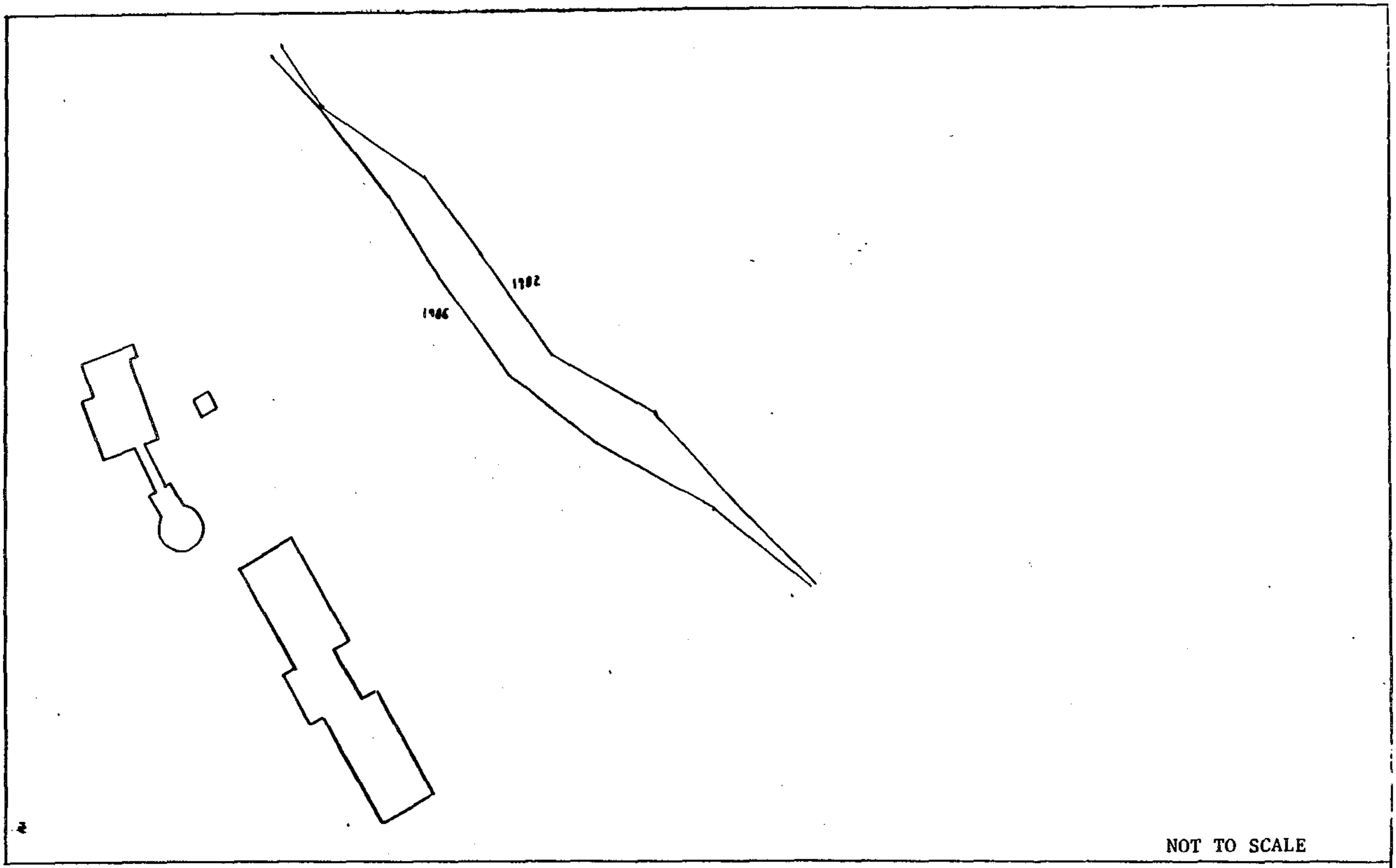


FIGURE 19 - MARCH 1982 AND 1986 SURVEY DATA PLOTTED AS SHORELINE CHANGE MAP

TABLE 4

SURVEY DATA IN TABULAR FORM

YEARLY SHORELINE POSITION, HIGHLAND LIGHT

STATION	MAY 82	MAY 83	MAY 84	MAY 85	MAY 86	MAY 87
A	18.5	16.33	16.33	16.33	15.42	14.17
B	9.33	8.92	8.92	8.92	7.5	7.5
C	25.58	25.58	25.58	24.42	8	6.5
D	10.5	8.75	8.75	8.25	-9	-11.25
E	22	21.92	21.92	21.92	7.5	2.5
F	26.5	24.67	23.42	23.17	3.75	-3.67
G	16.67	15.83	15.25	15.08	15.08	7.67
H	31.83	31	29.58	29.42	29.42	27.58

EROSION RATES

	82-83	83-84	84-85	85-86	86-87	AVE.82-87
A	2.17	0	0	0.91	1.25	0.866
B	0.41	0	0	1.42	0	0.366
C	0	0	1.16	16.42	1.5	3.816
D	1.75	0	0.5	17.25	2.25	4.35
E	0.08	0	0	14.42	5	3.9
F	1.83	1.25	0.25	19.42	7.42	6.034
G	0.84	0.58	0.17	0	7.41	1.8
H	0.83	1.42	0.16	0	1.84	0.85

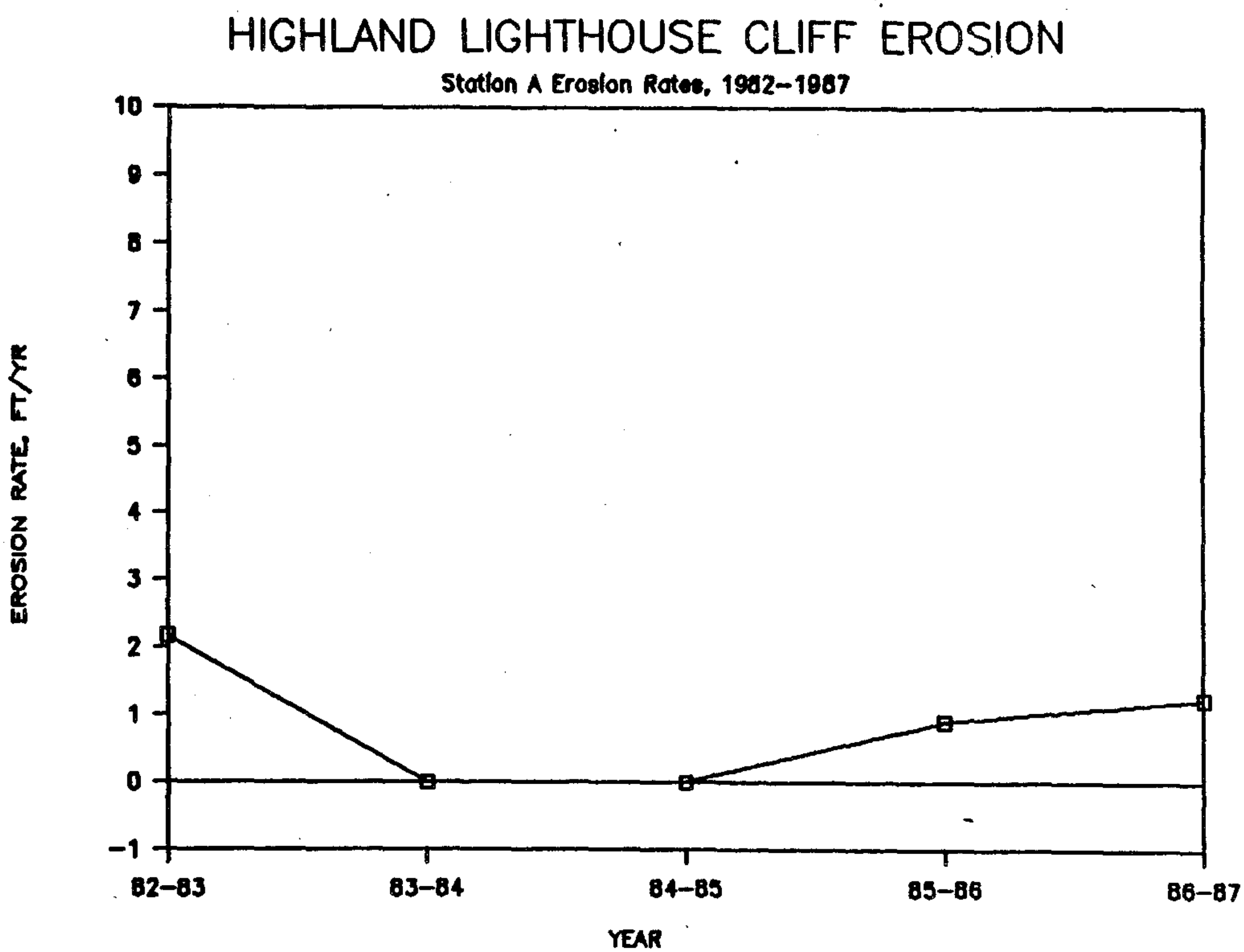

HIGHLAND LIGHTHOUSE CLIFF EROSION
Station A Erosion Rates, 1982–1987
EROSION RATE, FT/YR
10
9
8
7
6
5
4
3
2
1
0
−1
82–83
83–84
84–85
85–86
86–87
YEAR

FIGURE 20

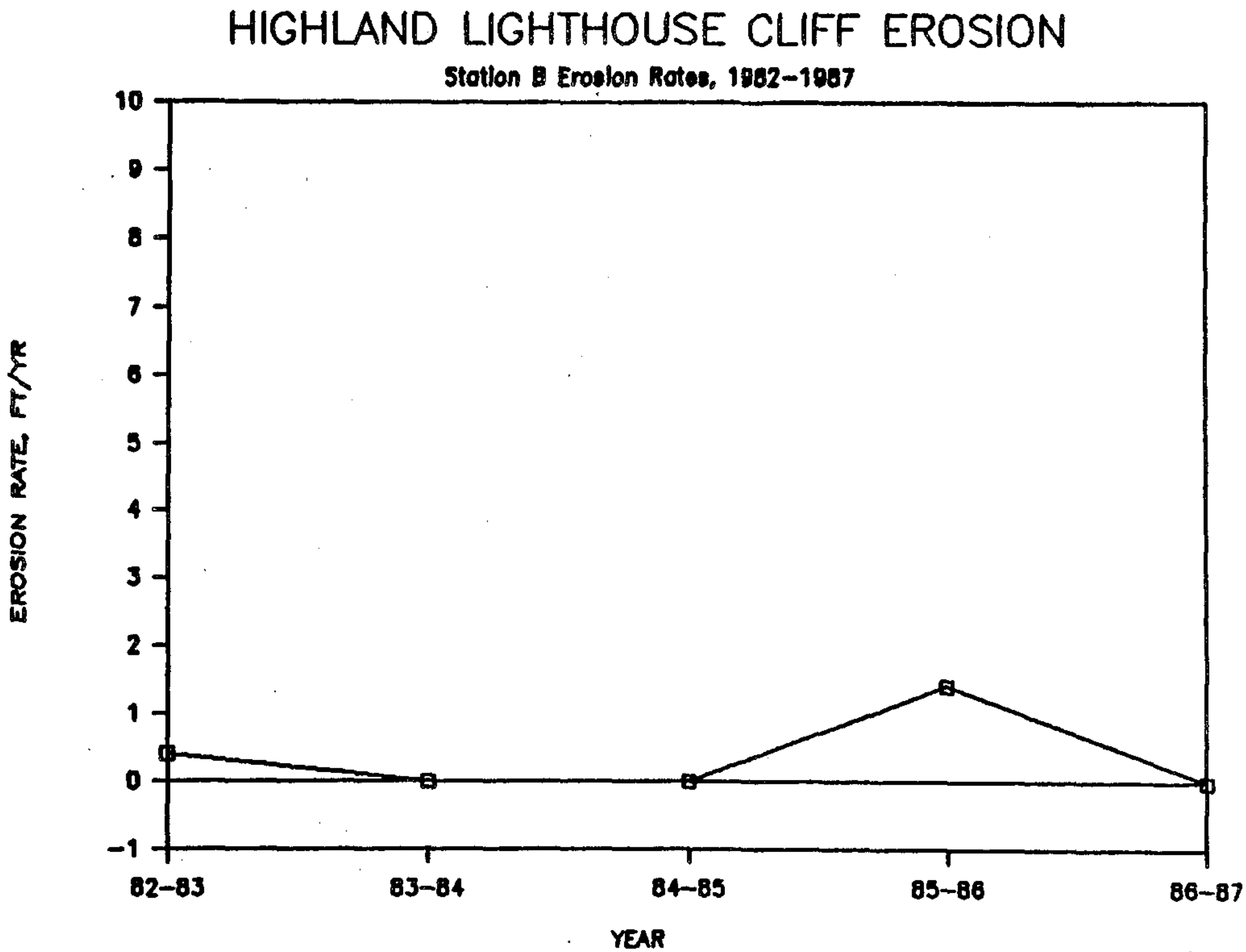

HIGHLAND LIGHTHOUSE CLIFF EROSION
Station B Erosion Rates, 1982–1987
EROSION RATE, FT/YR
10
9
8
7
6
5
4
3
2
1
0
−1
82–83
83–84
84–85
85–86
86–87
YEAR

FIGURE 21

HIGHLAND LIGHTHOUSE CLIFF EROSION

Station C Erosion Rates, 1982–1987

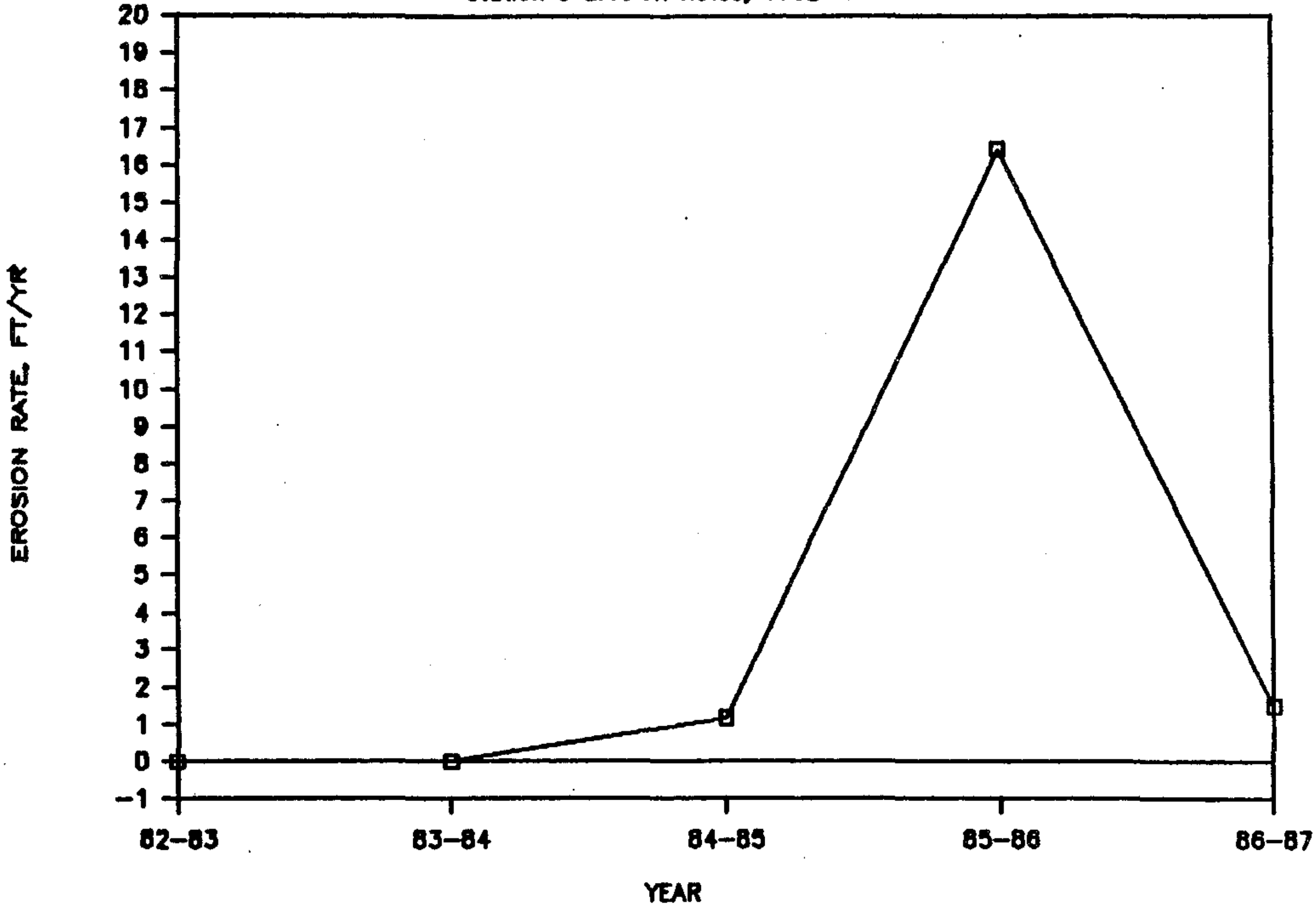


FIGURE 22

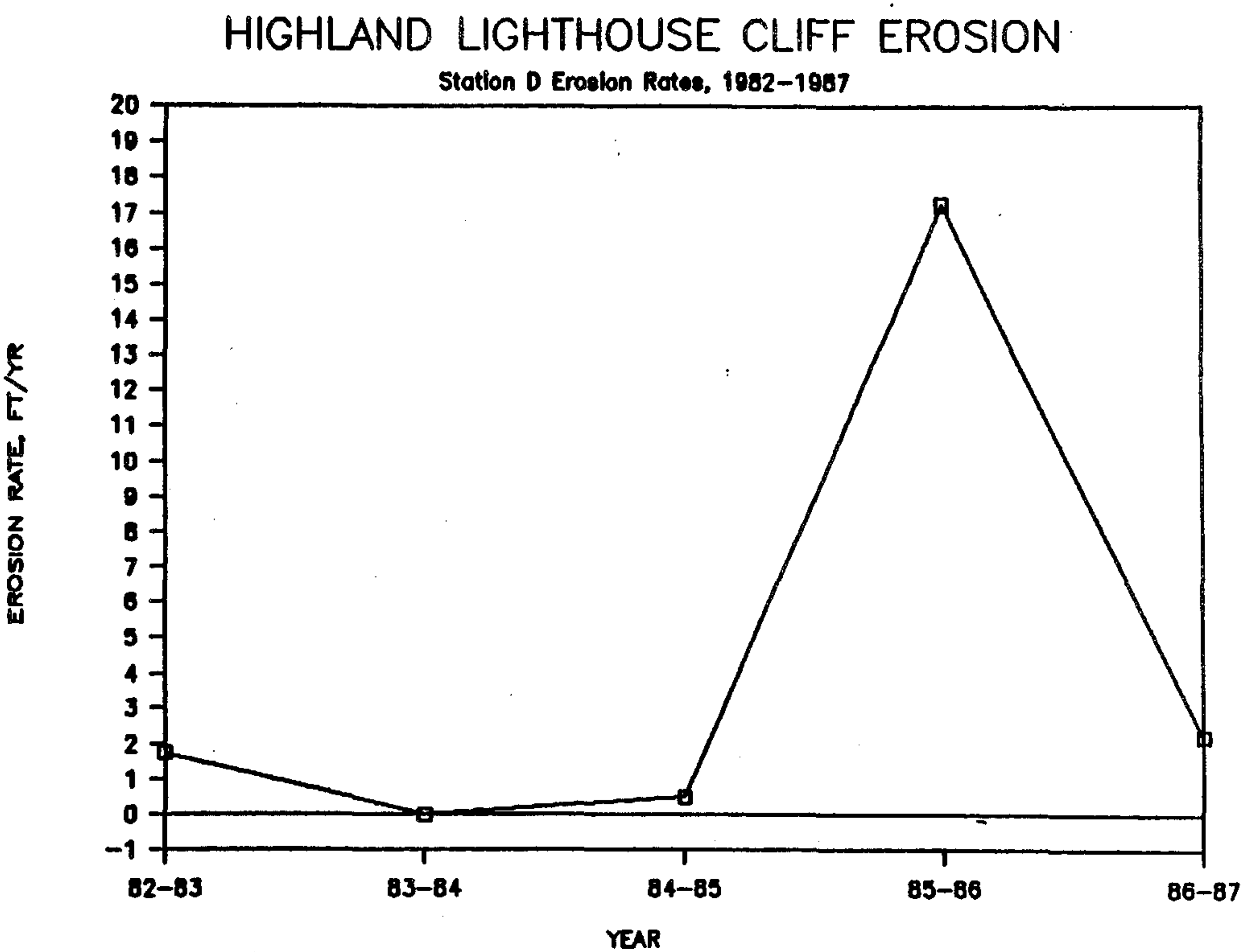

HIGHLAND LIGHTHOUSE CLIFF EROSION
Station D Erosion Rates, 1982-1987
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
EROSION RATE, FT/YR
82-83
83-84
84-85
85-86
86-87
YEAR

FIGURE 23

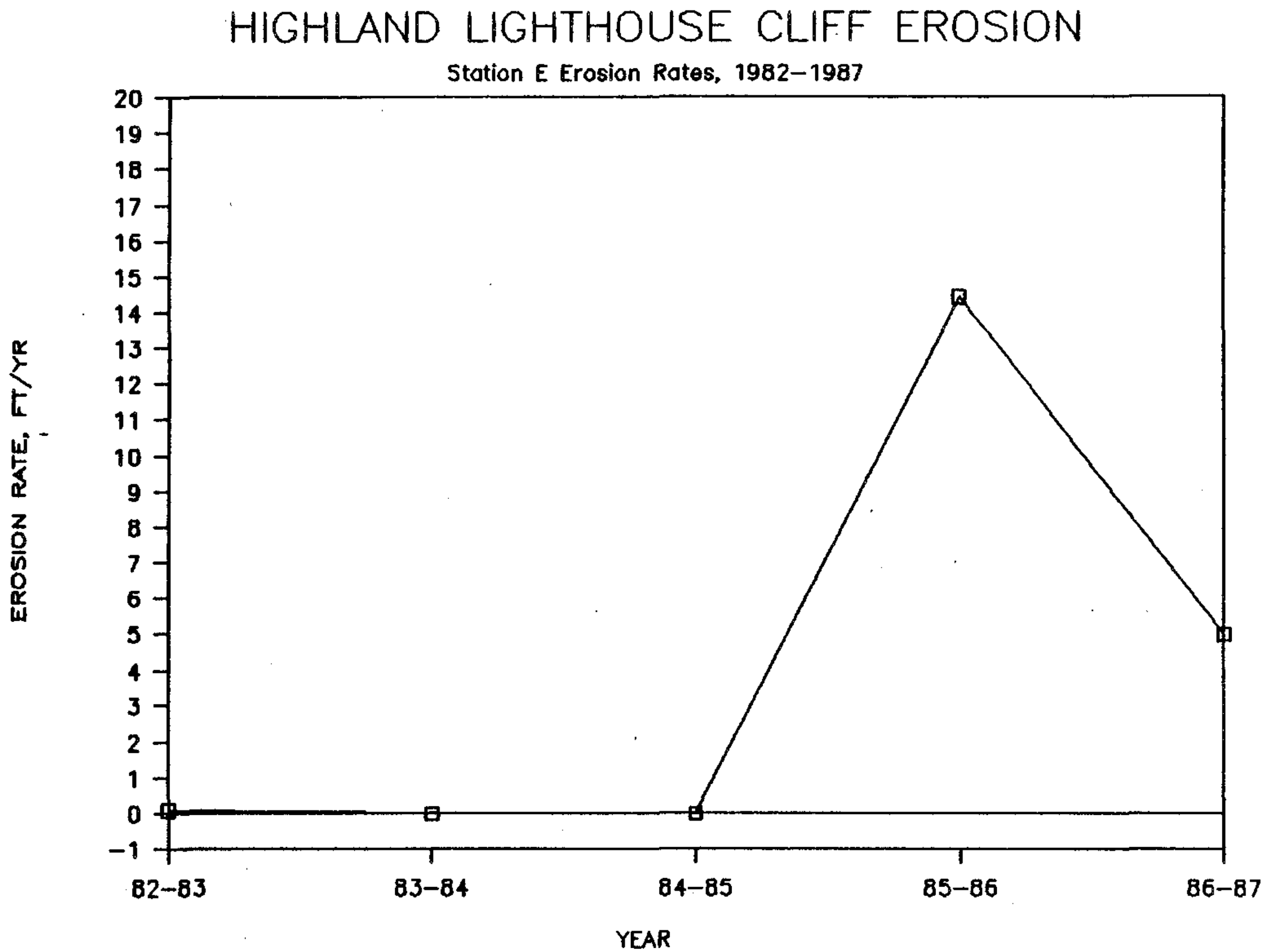

HIGHLAND LIGHTHOUSE CLIFF EROSION
Station E Erosion Rates, 1982–1987
EROSION RATE, FT/YR
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
–1
82–83
83–84
84–85
85–86
86–87
YEAR

FIGURE 24

HIGHLAND LIGHTHOUSE CLIFF EROSION

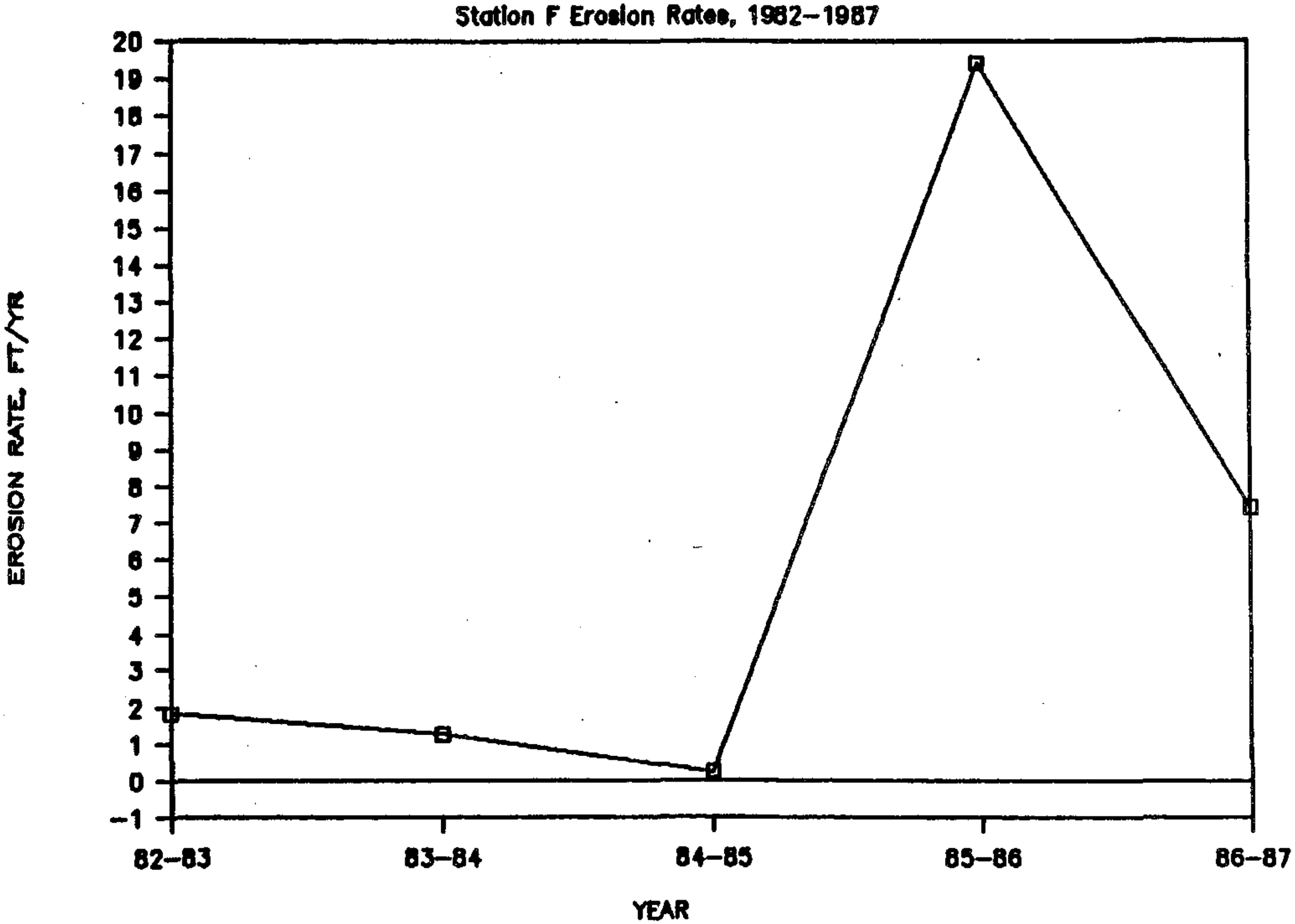


FIGURE 25

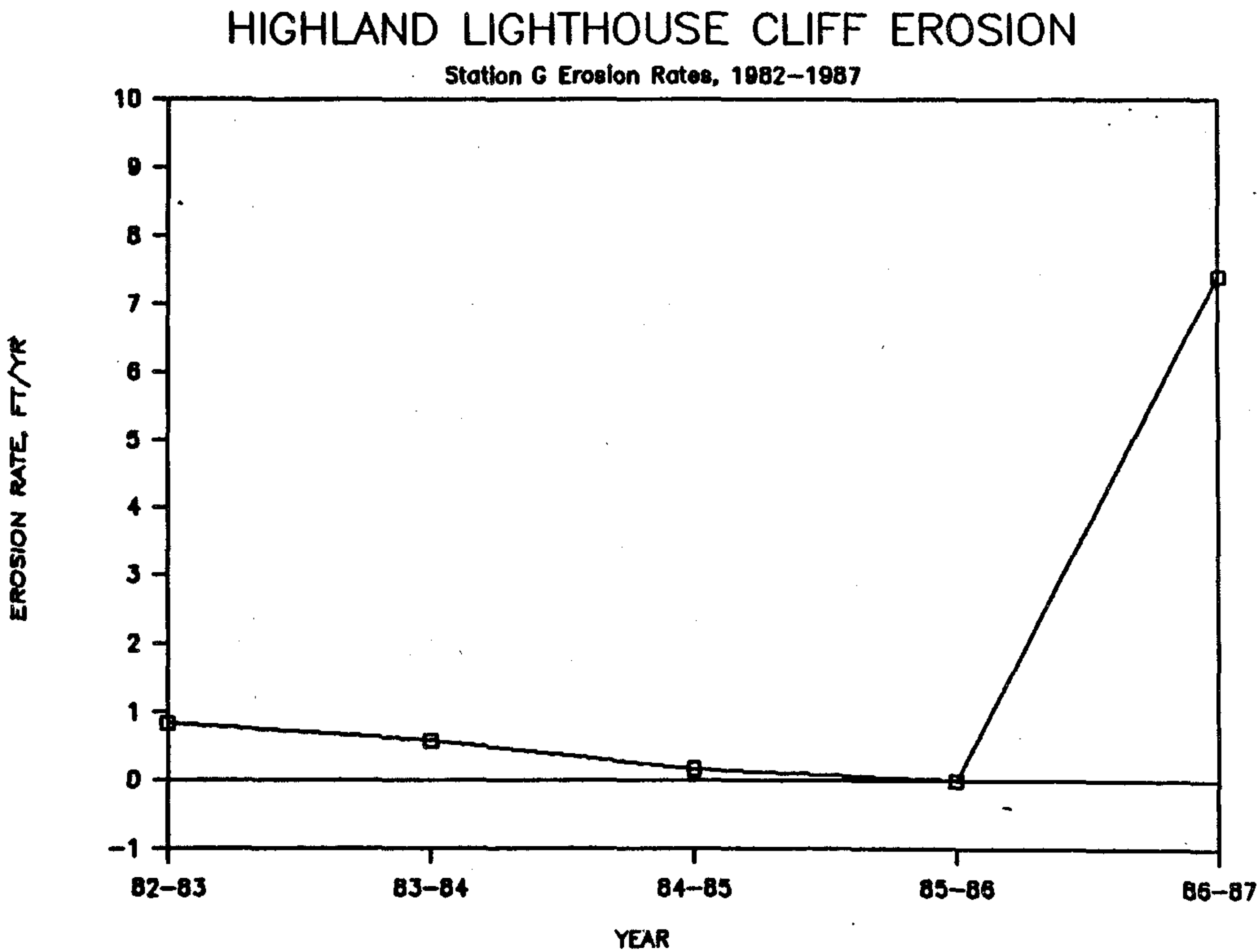

HIGHLAND LIGHTHOUSE CLIFF EROSION
Station G Erosion Rates, 1982–1987
EROSION RATE, FT/YR
10
9
8
7
6
5
4
3
2
1
0
−1
82–83
83–84
84–85
85–86
86–87
YEAR

FIGURE 26

HIGHLAND LIGHTHOUSE CLIFF EROSION

Station H Erosion Rates, 1982-1987

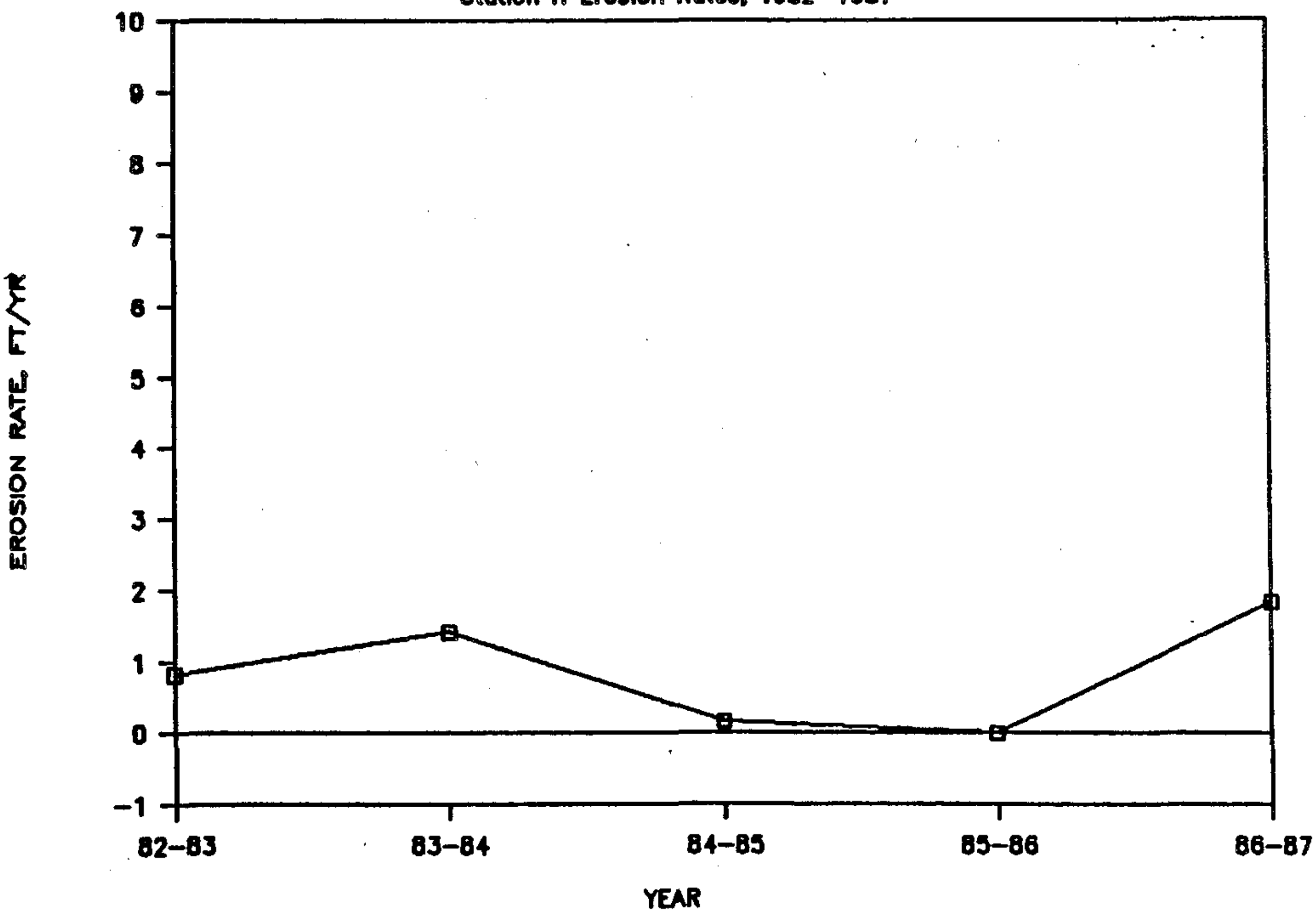


FIGURE 27

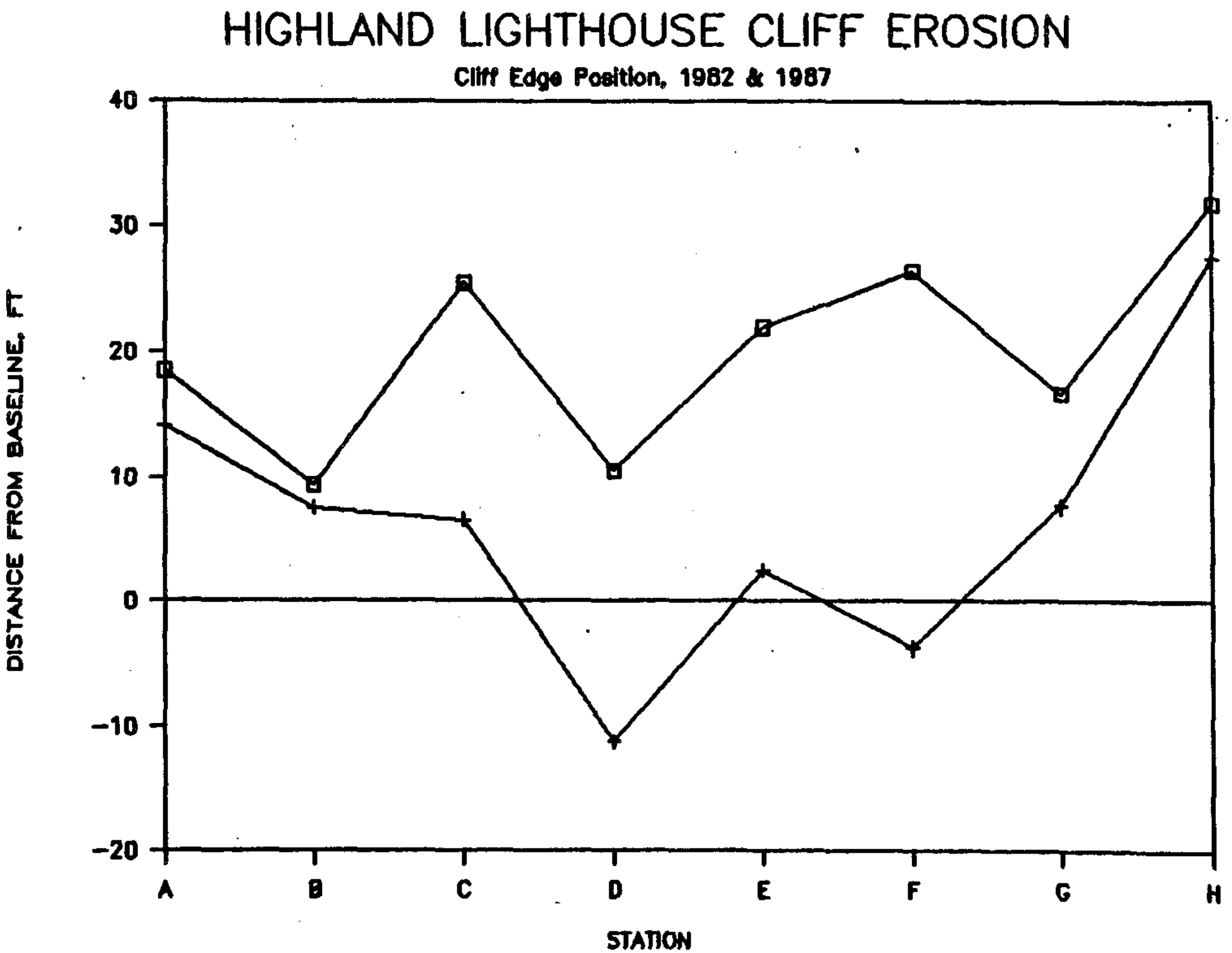

HIGHLAND LIGHTHOUSE CLIFF EROSION
Cliff Edge Position, 1982 & 1987
DISTANCE FROM BASELINE, FT
40
30
20
10
0
-10
-20
A
B
C
D
E
F
G
H
STATION

FIGURE 28

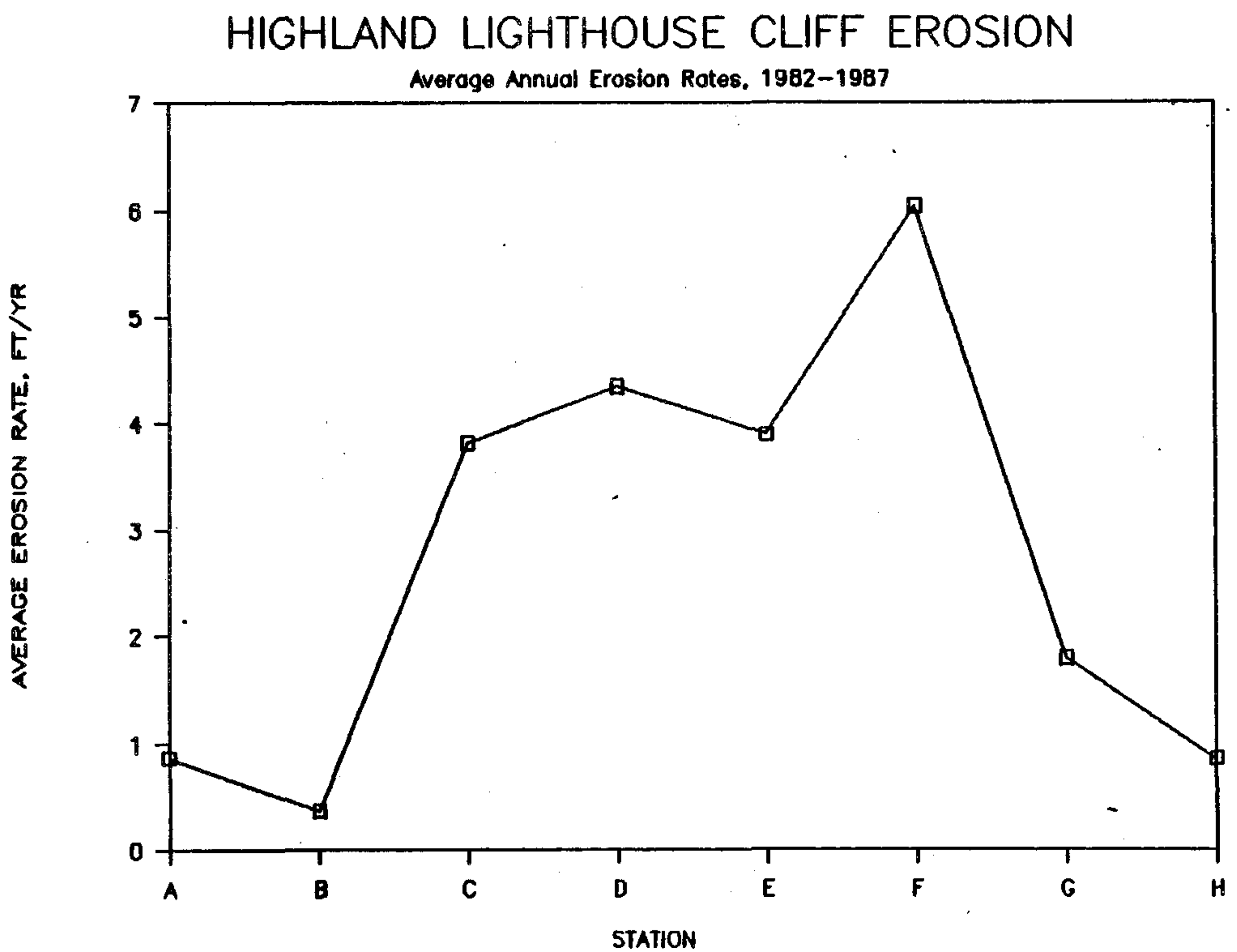

HIGHLAND LIGHTHOUSE CLIFF EROSION
Average Annual Erosion Rates, 1982–1987
AVERAGE EROSION RATE, FT/YR
0
1
2
3
4
5
6
7
A
B
C
D
E
F
G
H
STATION

FIGURE 29

APPENDIX 2

COST ESTIMATES AND SUPPLEMENTAL INFORMATION

APPENDIX 2
COST ESTIMATES AND SUPPLEMENTAL INFORMATION

TABLE OF CONTENTS

COST ESTIMATES

Cost estimates have been put in the net present value format and discounted at an interest rate of 10 percent over a 50 year period of analysis to permit a comparison of the costs of the alternatives in accordance with the Economic Analysis Handbook (July 1980)-NAVFAC, p. 442.

ALTERNATIVE 1 - MEASURING BANK SLIPPAGE FOR EARLY WARNING

No formal cost estimate was prepared for this alternative since it would only give early warning of the failure of the bank, and there are many different ways of measuring the slippage. There is however, in this appendix, a letter pertaining to this alternative on pages A2-6 and A2-7.

ALTERNATIVE 2 - VEGETATION ON CLIFF WITH STRUCTURAL SLOPE STABILIZATION

No formal cost estimate was prepared for this alternative since there are so many choices as to the materials to use for the structures and the vegetation. There is a newsclipping in this appendix on pages A2-8 and A2-9 with information on a slope stabilization taking place on Montauk Point (Long Island) bank.

ALTERNATIVE 3 - SANDFILL

FIRST COST

Sandfill	41,360 cy @ $10/cy	$ 414,000
Subtotal		$ 414,000
Engineering and Design		50,000
Subtotal		$ 464,000
Supervision and Administration		50,000
Subtotal		$ 514,000
Contingencies		106,000
TOTAL FIRST COST		$ 620,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$ 620,000
Periodic Nourishment*	1,660,000
NET PRESENT VALUE	$2,280,000

* Note - Due to the fact that the area is so dynamic, it is estimated that without the use of any structures, the entire amount of sandfill will be lost 4 times each year.

ALTERNATIVE 4 - GROINS

FIRST COST

Rock	14,740 tons @ $40/ton	$ 590,000
Subtotal		$ 590,000
Engineering and Design		50,000
Subtotal		$ 640,000
Supervision and Administration		50,000
Subtotal		$ 690,000
Contingencies		140,000
TOTAL FIRST COST		$ 830,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$ 830,000
Annual Maintenance at $7,000/yr x (9.9)	$ 70,000
NET PRESENT VALUE	$ 900,000

ALTERNATIVE 5 - SANDFILL WITH GROINS

FIRST COST

Sandfill	41,360 cy @ $10/cy	$ 414,000
Rock	14,740 tons @ $40/ton	590,000
Subtotal		$1,004,000
Engineering and Design		80,000
Subtotal		$1,084,000
Supervision and Administration		80,000
Subtotal		$1,164,000
Contingencies		236,000
TOTAL FIRST COST		$1,400,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$1,400,000
Annual Nourishment and maintenance at $810,000 x (9.9)	8,020,000
NET PRESENT VALUE	$9,420,000

ALTERNATIVE 6 - REVETMENT

FIRST COST

Rock	45,000 tons @ $45/ton	$2,025,000
Subtotal		$2,025,000
Engineering and Design		200,000
Subtotal		$2,225,000
Supervision and Administration		200,000
Subtotal		$2,425,000
Contingencies		575,000
TOTAL FIRST COST		$3,000,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$3,000,000
Annual Maintenance at $70,000 x (9.9)	$ 690,000
NET PRESENT VALUE	$3,690,000

ALTERNATIVE 7 - BREAKWATER

FIRST COST

Rock	70,000 tons @ $40/ton	$2,800,000
Subtotal		$2,800,000
Engineering and Design		200,000
Subtotal		$3,000,000
Supervision and Administration		200,000
Subtotal		$3,200,000
Contingencies		700,000
TOTAL FIRST COST		$3,900,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$3,900,000
Annual Maintenance at $75,000 x (9.9)	$ 740,000
NET PRESENT VALUE	$4,640,000

ALTERNATIVE 8 - ARTIFICIAL SEAWEED

No formal cost estimate was prepared for this alternative since it would not be effective in this area.

ALTERNATIVE 9 - MOVING THE EXISTING STRUCTURE

Preliminary inquires indicate that the cost of relocating the existing lighthouse could be about $500,000. See the letter from LaPlante - Adair Co., Contractors and Moving Engineers in page A2-17. A cost of $600,000 has been used in this study to allow for structural modifications.

FIRST COST

Relocation	$ 600,000
Engineering and Design	50,000
Subtotal	$ 650,000
Supervision and Administration	50,000
Subtotal	$ 700,000
Contingencies	100,000
TOTAL FIRST COST	$ 800,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$ 800,000
Annual Maintenance at $8,000 x (9.9)	$ 80,000
NET PRESENT VALUE	$ 880,000

ALTERNATIVE 10 - CONSTRUCTING A NEW LIGHTHOUSE

According to the U.S. Coast Guard, the construction of the new Great Point Lighthouse, Nantucket, Massachusetts was completed in late 1985 at a cost of approximately $1,000,000. Planning estimates put the cost of construction of a new lighthouse in North Truro between $1,100,000 and $1,500,000. This study estimates a construction cost of $1,300,000..

FIRST COST

Constructing new lighthouse	$1,300,000
Engineering and Design	100,000
Subtotal	$1,400,000
Supervision and Administration	100,000
Subtotal	$1,500,000
Contingencies	300,000
TOTAL FIRST COST	$1,800,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$1,800,000
Annual Maintenance at $5,000 x (9.9)	$ 50,000
NET PRESENT VALUE	$1,850,000

SUPPLEMENTAL INFORMATION ON SPECIFIC ALTERNATIVES

The newspaper articles and correspondence which follow are supplied in order to help with the selection of the final alternative plan. This information is supplied for information purposes only and may be helpful in the final design of the selected alternative.

ALTERNATIVE 1 - MEASURING BANK SLIPPAGE FOR EARLY WARNING

Howard B. Dutro

P.O. Box 191
Delmont, S.D. 57330

Phone
Office: 605-779-3201
Home: 605-779-3191

January 18, 1988

Mr. Tom Chisholm
Dept. of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Chisholm:

Thank you for your letter of 11 January, describing slope failures adjacent to the lighthouses.

Probably most sea cliff failures are due to toppling induced by wave erosion at cliff bases. However, looking at the photos you enclosed, the slope angles look a little too flat for this to have been the primary mode. I wonder if some of the failures may be due to percolation of water downward to impermeable layers which dip toward the sea, with subsequent outward movement of the blocks along these layers?

If so, the initial and subsequent displacements of unstable blocks could be detected using Multiple Position Borehole Extensometers. The instruments could be installed in holes drilled either from the surface immediately behind the crest of the slope or from the slope face, depending on the attitude of the potential failure plane or planes. If, on the other hand, toppling were to be the principal mode of failure, tilt meters could be used to detect early rotation of failing blocks.

My own preference is for borehole extensometers because the can be arranged to test greater expanses of ground, and because they can detect displacements of extremely small magnitudes. This is important because, of course, the name of the game is to detect impending problems early enough to permit remedial action to be taken. If in fact some of the problems are due to water migration along impermeable beds, the most likely remedies would be dewatering of the overlying permeable beds and diversion of rainfall or snowmelt sources in the area behind the cliff.

If either your office or the Coast Guard can give me a more detailed description of the geology; i.e., the character, strike, dip, thickness, etc. of the beds, I will be happy to make a more detailed proposal. In the meantime, I would guess that a typical borehole extensometer equipped with eight mechanical transducer and dimensioned for installation in a 400 ft. 3 to 4 inch hole might cost about $3,000 (plus drilling and installation labor). The 400-ft length would place the point of the hole well inshore from the lighthouse, thus referring subsequent measurements to a point presumably stable and fixed in space. Sensitivity would be on the order of 0.001 inches or greater, with a useful range of several inches. Generally, the hole would be inclined with respect to the bedding, in order to intersect as many potential failure planes as possible at angles of perhaps 25 to 45 deg. Such an instrument would be read out using a depth micrometer or vernier caliper.

A similar instrument could be provided, but with remote electronic readout, at a cost of perhaps $6,000 - $7,500. I personally favor the simpler and less expensive mechanical variety, for several reasons. I would prefer to see the extra money put into additional instruments, rather than into possibly pointless refinements. I also think it is a good idea to have a living, breathing person at the site as frequently as possible not only to make regular engineering observations but also to inspect and maintain the instruments. Finally, I am opposed to the general idea which seems to be implicit in some forms of instrumentation which is to automate data acquisition and record data en masse. This seems to me to be relegating perhaps one of the most critical tasks in geotechnical engineering to people who understand the computer-based data acquisition apparatus, regardless of how well or how poorly they understand the fundamentals nature and risks of the problem.

At any rate, let me know what further information I can provide. I have added your name to Terrasciences' mailing list, and I am enclosing two copies of the "Field Notes" issue you have already seen.

I am sending a copy of this letter along to Gordon Patrick, so that he will know you and I are in contact. Gordon and I fought the good fight on a number of projects for the Corps of Engineers, notably slope instrumentation at Libby Dam (Montana) and instrumentation of a sensitive foundation at Green Peter Dam (Oregon). Among many other projects I have been involved in for the COE are Raystown Lock and Dam (Maryland), Hannibal Lock and Dam (Pennsylvania), Clarence Cannon Dam (Missouri), Carters Dam (Georgia), Bankhead Lock and Dam restoration (Alabama), Stockton Dam (Missouri), Chatfield Dam (Colorado), Snetisham Pumped Storage Project (Alaska), and on and on.

With thanks again for your interest in contacting me, I remain,

Yours very truly,

Howard Dutro

Howard B. Dutro

enc.

ALTERNATIVE 2 - VEGETATION ON CLIFF WITH STRUCTURAL SLOPE STABILIZATION

Woman 'holds up' Montauk Poin[t] bank

By PATTY KOLLER

Thick fog lent a desolate air to Montauk Point, N.Y., a surf-swept area on the eastern tip of Long Island. Through the mist one November afternoon, 77-year-old Giorgina Reid deftly stepped up a terraced 45-degree slope to meet a visitor.

"Count to 16 and hold your ears," warned Reid. A skull-splitting fog horn near the Montauk Lighthouse intermittently blasted only a few yards away, atop the steep bluffs that raise Montauk Point up some 85 feet above the ocean.

Over the course of 15 years, Reid has almost single-handedly transformed the once-eroding sand cliffs into beach-grass-covered slopes.

Reid is well acquainted with the horn's characteristics and, for that matter, most all of the specifics of the 189-year-old lighthouse. Since 1970 the Queens, N.Y., resident has once or twice a week traveled by car the length of Long Island to get there.

Armed on these biweekly visits with rake, hoe, lumber, bags of reeds and Donald, her husband of 52 years, Reid has, in a somewhat simplistic explanation, graded the bluffs to an angle of 45 degrees or less, formed terraces by placing boards horizontally across the resulting slopes, filled the spaces behind the boards with reeds and sand, then waited as beach grass took hold.

"I was amazed to find that beach grass came up of its own accord once I stilled the sand," said Reid. "The (grasses) need peace and quiet — we all do to grow."

Reid's efforts at Montauk Point follow her own method of erosion control that she calls "Reed-Trench Terracing". It is all outlined in a book she wrote — "How to Hold Up A Bank" — and in Letters Patent 3,412,561, on file with the U.S. Patent Office since 1968.

In what amounts to a monumental change of course, the bank at Montauk Point upon which Reid has been toiling for so long is now "holding up beautifully," said Coast Guard Petty Officer W. Gene Hughes, who is keeper of the Montauk Lighthouse.

President George Washington commissioned the Montauk Lighthouse, one of the oldest in the nation, and when it was completed in 1797 its sturdy base rested 297 feet from the edge of the high bluff above the ocean. By the late 1960s only 60 feet of that land remained — the wind, rain and strong-of-heart climbers having made relatively quick work of eroding the rest.

In the late 1960s Reid learned of the situation from friends who fished at Montauk. "They said the lighthouse would fall into the sea by 1985," recalled Reid, a tiny woman who appears to be 20 years younger than her actual age. "I wanted to get my paws at it."

REEDS, according to Giorgina Reid, are the key to her ero[sion] control method. Here she places them in terraces that will e[ven]tually grow beach grass and stabilize the bank below the M[on]tauk (N.Y.) Lighthouse.

Reid's paws stopped the erosion in its tracks — today the edge of the cliff remains where it was when she started.

She originally developed her erosion control method in order to save her bluff-top summer home on Long Island's north shore after a 1962 storm devastated the cliff only 15 feet away. The storm littered the beach below with the reeds that became "the nucleus of my method," said Reid, her face windburned and her navy blue coat dusted with sand.

The reeds, she explained, serve as gaskets — they keep the sand from slipping out f[rom] under the boards that cont[ain]ing the terrace, and they s[uck] water up to grass roots thro[ugh] capillary action. After [the] grasses take hold, the bo[ards] can be removed and the b[ank] will remain stable.

Reid said that taking o[ut a] patent on the method wasn['t to] make money but to ensure [that] if it's done wrong, she won['t be] blamed for it.

Contractors hired by [the] Coast Guard in 1971 to ar[rest] the erosion, at Montauk P[oint] after Reid demonstrated [that] the technique worked, di[d it] wrong, Reid said.

Nonetheless, the Coast G[uard] has been helpful to Reid's [proj]ect, throughout the years [con]tributing more than $150[...]. Reid's husband figures, [she] said, that the couple has s[pent] close to $40,000 of their [own] money on the Montauk proj[ect].

"Over the years it doe[sn't] matter, it goes bit by bit," [said] Reid, who broke her ankle [last] spring while working on [the] bluffs.

By now Reid has compl[eted] most of the work the feder[ally] owned banks of Montauk P[oint] require. The rest is owned [by] the state, and Reid flatly s[ays] "the state has no money." [No] money, that is, to spend [on] Reid's erosion control proje[ct].

1062

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"Her work is not going to mean anything on the Coast Guard property unless the state does their part," said Hughes.

Reid has estimated that she needs $50,000 to complete her work — 300 linear feet of bluff on the state side — and fully protect the Montauk Lighthouse from crumbling with Montauk Point into the ocean.

But at this point, the money isn't likely to come from the state of New York.

"We don't have the money in the budget at the present time," said John Sheridan, general manager of the Long Island State Park Commission. Sheridan said he has heard nothing of late from either Reid or the federal government on the specifics of Reid's erosion project and has received no indication on how Reid plans to spend $50,000. There are 25 state parks in Nassau and Suffolk counties, he said, and "each of those has a Giorgina Reid-type project."

If the state were to deem it worthwhile to sink money into the project, Sheridan said, a contract process would follow. "Maybe what Mrs. Reid has in mind would cost $30,000 under public bid."

That's not likely to sit well with Reid, who has already demonstrated her preference for doing the work rather than watching someone else do it incorrectly.

"It's a long, painstaking process she goes through," said Hughes, who has watched her go through it for the two years he's been stationed at the Montauk Lighthouse. "It works well but it takes care — it's not the type of work you can contract out."

Reid said that she was doing the best she could on the state side with the limited resources at her disposal. She had also formed a non-profit organization — the Montauk Point Erosion Control Project, Box 995, Montauk, N.Y. 11954 — so she could collect donations to continue her work.

"The lighthouse is my only child," said Reid, wrapping up her theories about erosion control. "You've got to give or it will be taken from you."

2 of 2

ALTERNATIVE 9 - MOVING THE EXISTING STRUCTURE

LaPLANT-ADAIR CO. • *Contractors and Moving Engineers*

1200 WEST INDUSTRIAL AVENUE
BOYNTON BEACH, FLORIDA ~~33435~~ 33426
PHONE (305) 737-8188

February 10, 1988

Mr. Tom Chisholm, Engineer
CENEDPL-C
Corp. of Engineers
424 Trapelo Road
Waltham, Massachusetts 92254

Dear Mr. Chisholm:

We are enclosing a few reproductions of photographs showing four or five interesting jobs we have completed.

Not shown are the hundreds of buildings, several entire towns, several bridges, 30 to 35 additional elevated tanks, heavy machinery, chimneys, and other heavy and difficult moves.

Whenever you are ready to proceed with this work we will be glad to work with you. If you so desire, we can visit you and advise you as to the practical applications necessary to successfully complete the relocation of the lighthouses you wish to be moved. For this inspection service we charge $500.00 per day portal-to-portal, plus all travel expenses.

Please advise if we can be of service to you, and call us collect at Area Code 305, 737-8188. Effective April 16th, our new Area Code will be 407.

Respectfully submitted,

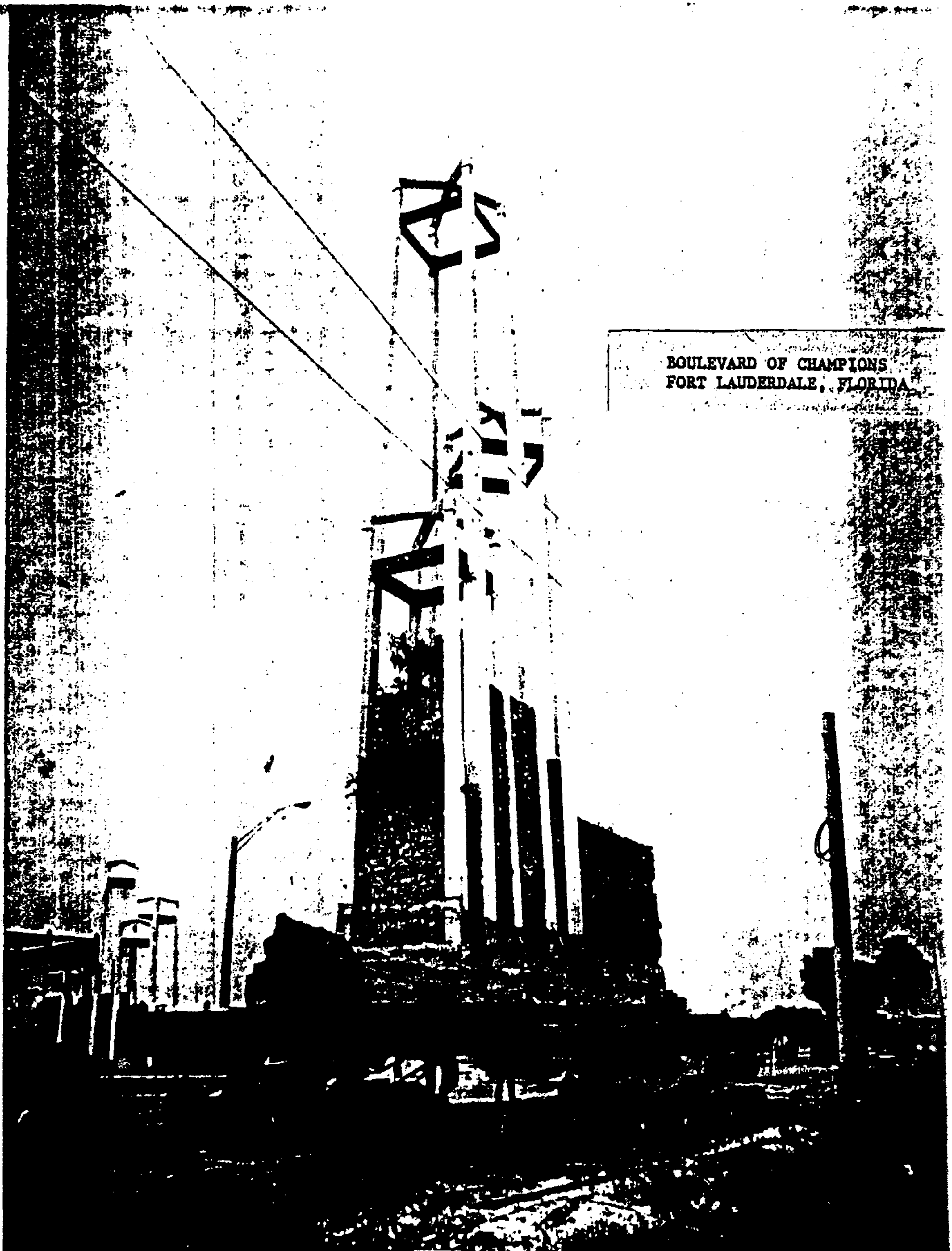
LaPLANT-ADAIR CO.

K. F. Adair

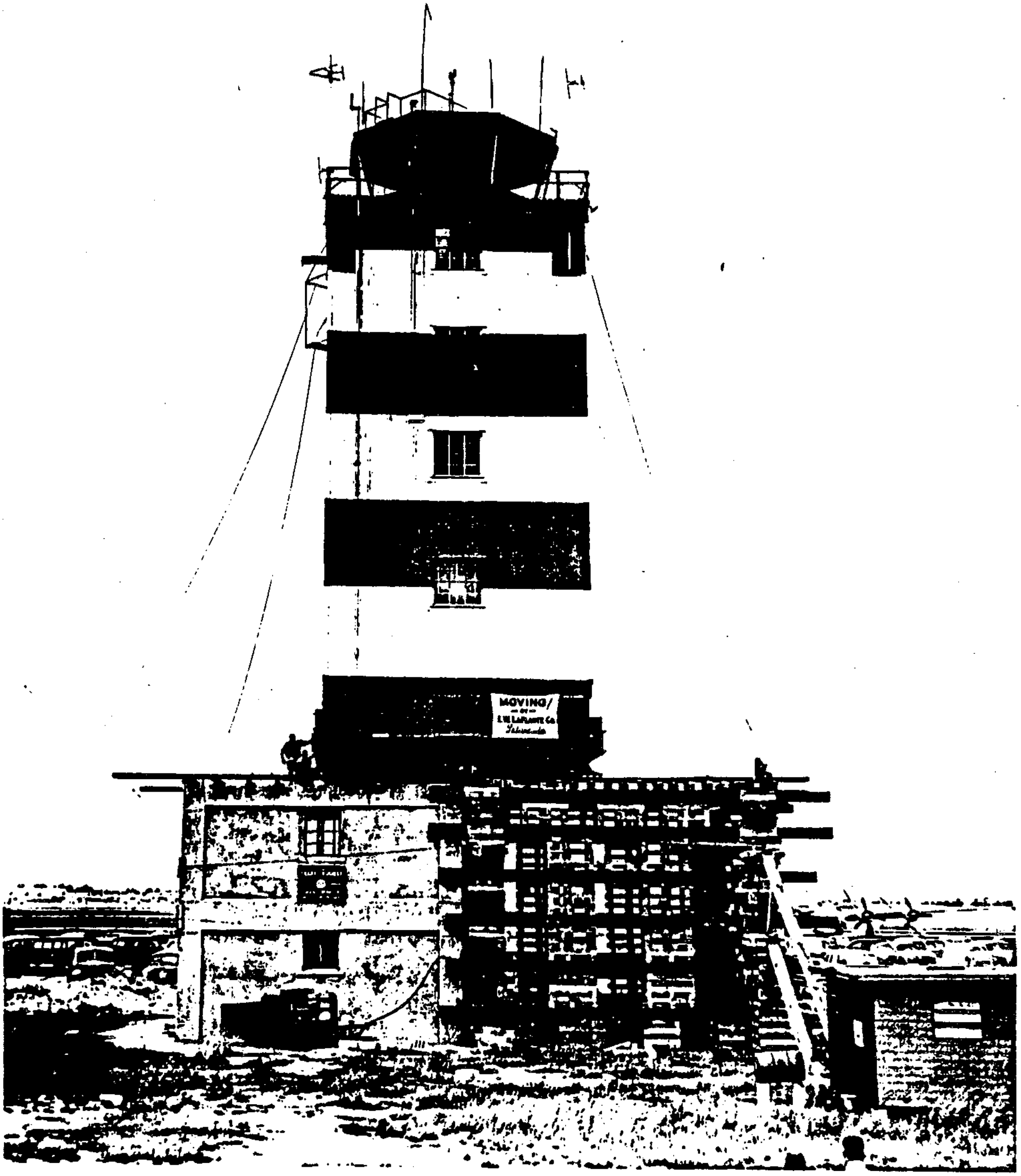
K. F. ADAIR

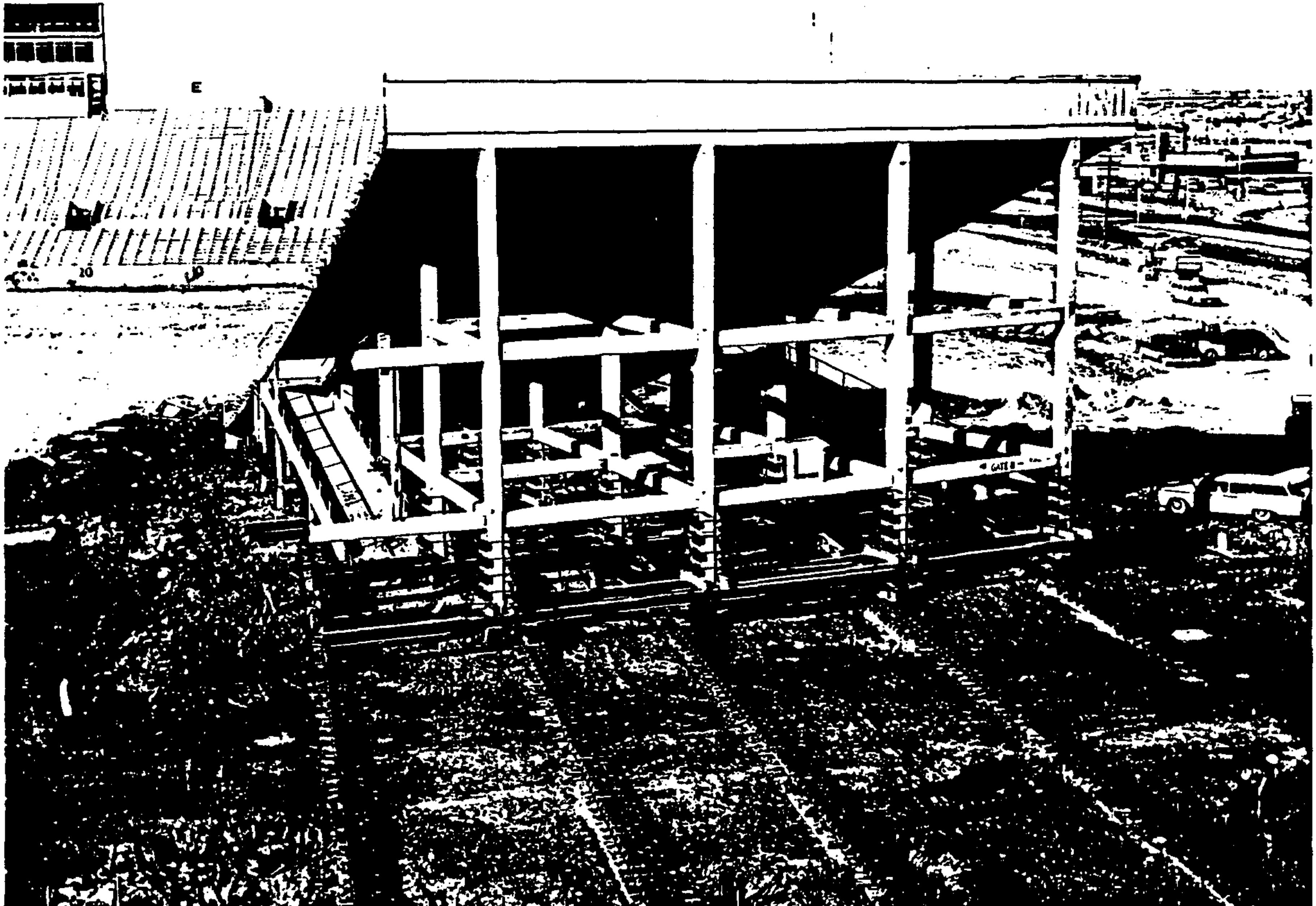
KFA;mm


Lake Pointe



BOULEVARD OF CHAMPIONS
FORT LAUDERDALE, FLORIDA


MOVING



LaPLANT-ADAIR CO. • *Contractors and Moving Engineers*

1200 WEST INDUSTRIAL AVENUE
BOYNTON BEACH, FLORIDA ~~33435~~ 33426
PHONE (305) 737-8188

March 10, 1988

Mr. Tom Chisholm, Engineer
CENEDPL-C
Corp. of Engineers
424 Trapelo Road
Waltham, Massachusetts 92254

Dear Mr. Chisholm:

In our study regarding the relocation of a lighthouse in Massachusetts (size 18'wide x 65' high), we were hampered in not having full information regarding construction details, land conditions, location, etc.

However, working backwards, we came up with the idea that the walls at the base must be 4' thick with a spiral stairway about 3' wide, which leaves us with approximately 5680 pounds per square foot of wall, which is well within the soil capacities and bearing capacities of the masonry.

Considering the above, we believe your budget for the moving only should be $400,000 to $500,000.

In the event you would like a guaranteed figure, we will furnish same for the cost of an inspection survey as quoted in our letter of February 10, 1988, which is $500.00 per day plus all travel expenses portal-to-portal.

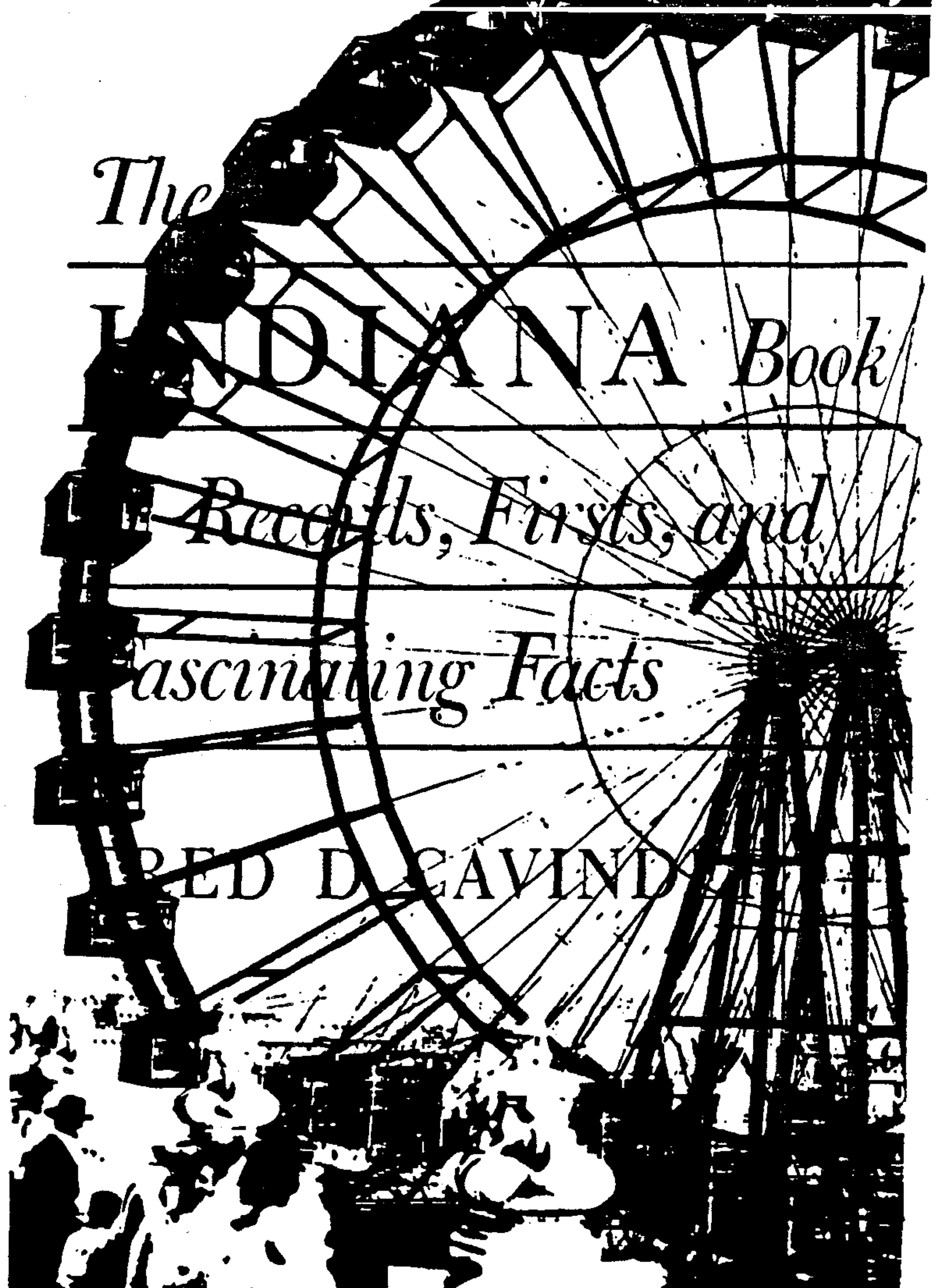
Respectfully submitted,

LaPLANT-ADAIR CO.

K F Adair mm

K. F. ADAIR

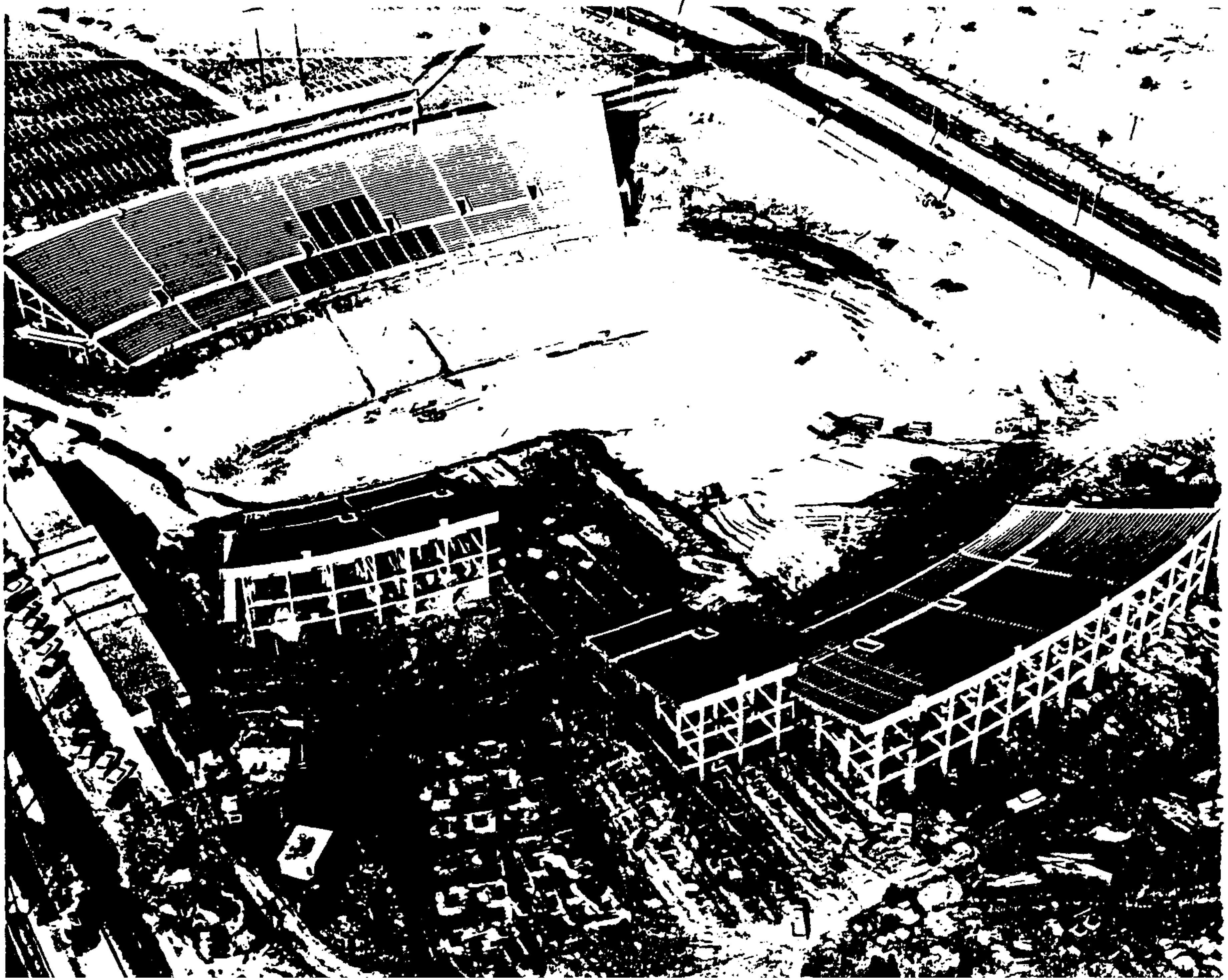
KFA;mm

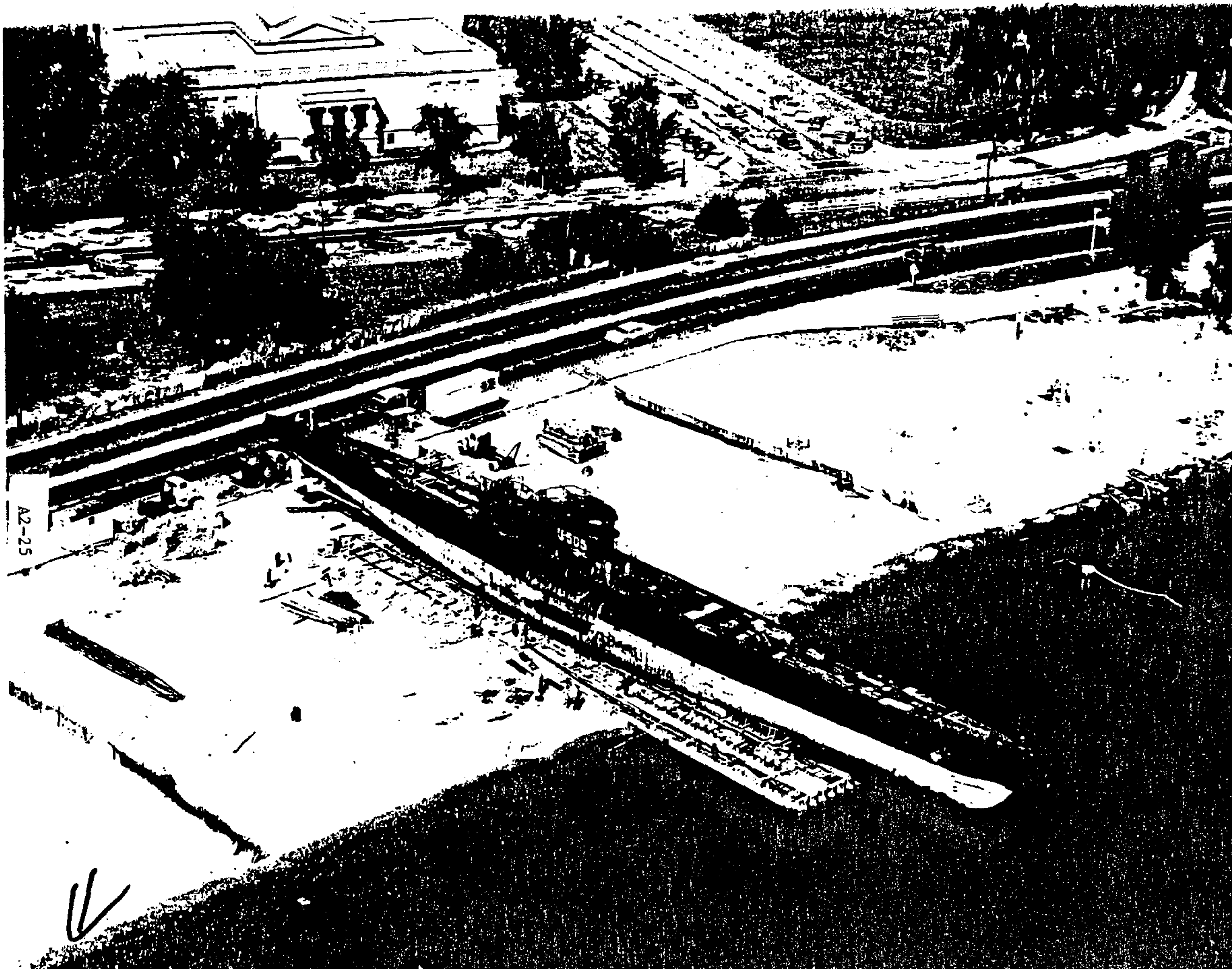


THE *first company to move a water tower*, still containing the water, *and to elevate a bridge without disrupting traffic* was the LaPlante-Adair Company of Indianapolis. The water tower, containing 160,000 gallons, was moved in 1957 at the Ford plant in Atlanta, Ga. The 1,500-foot bridge at Lincolnton, Ga., was raised 17 feet in 1951 to allow for a higher dam downstream. The bridge weighed 4,000 tons. In 1964 the same Indianapolis-based firm *moved a German submarine* from Lake Michigan across the Outer Drive to the Museum of Science and Industry in Chicago in nine hours while crowds of up to 15,000 persons watched. The firm later moved from Indianapolis to Florida. A2-22

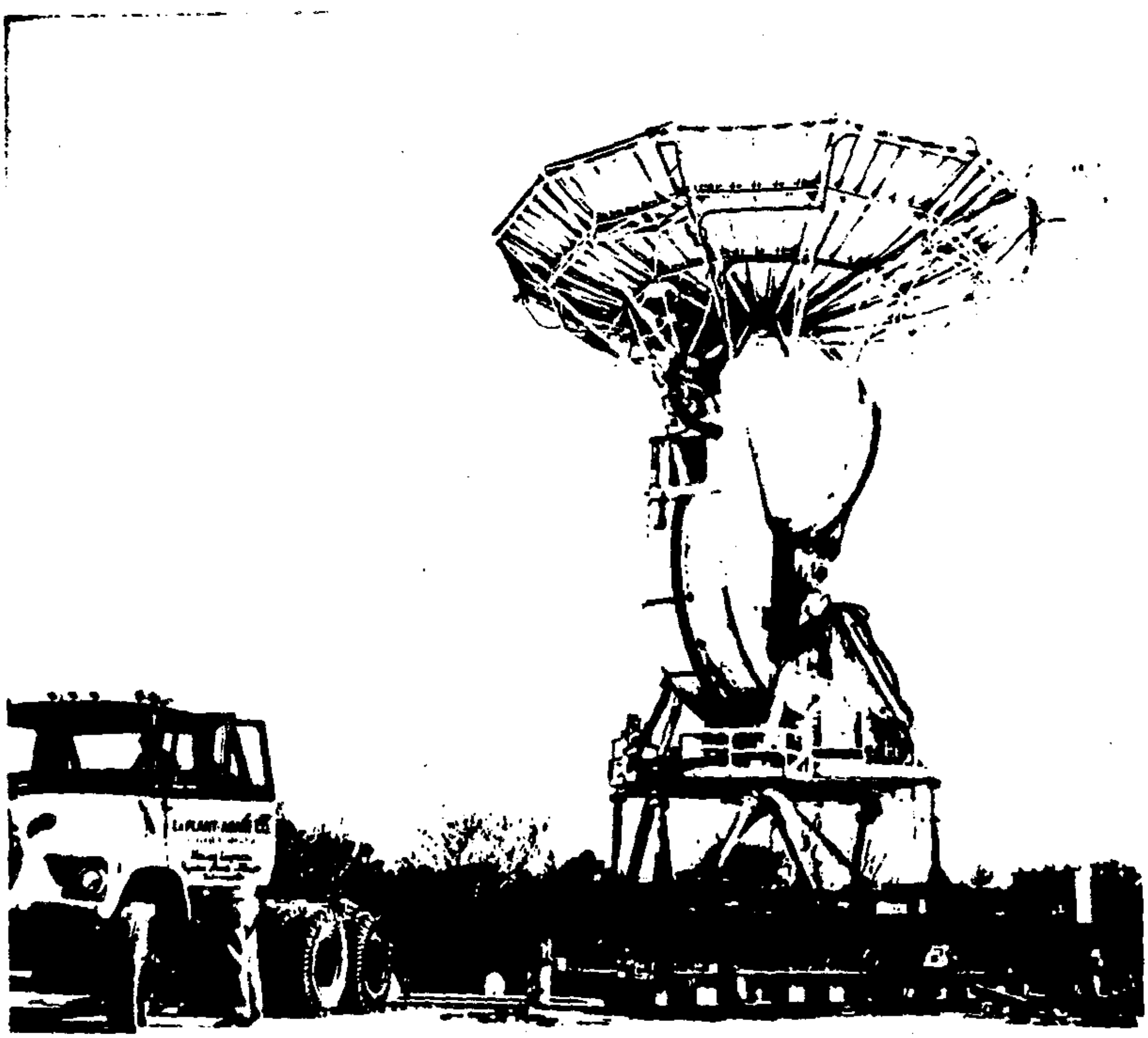
THIS IS THE FIRST ELEVATED TANK OF THIS TYPE TO BE MOVED.

OKKFA



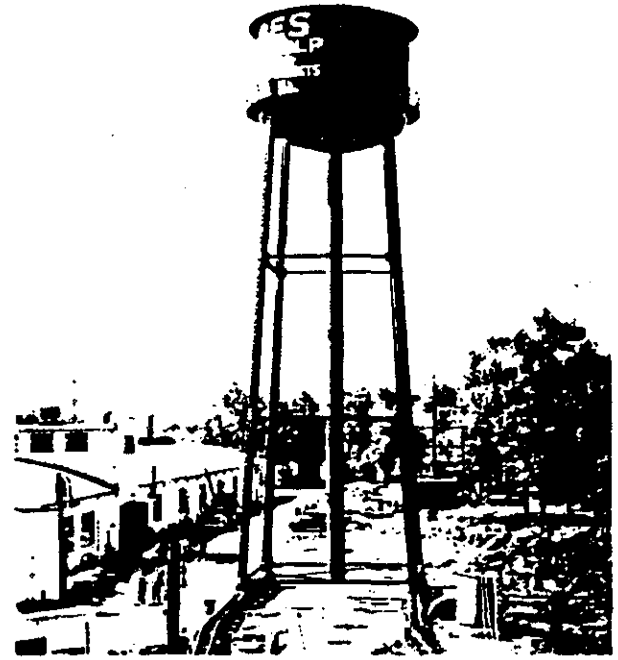


A2-25

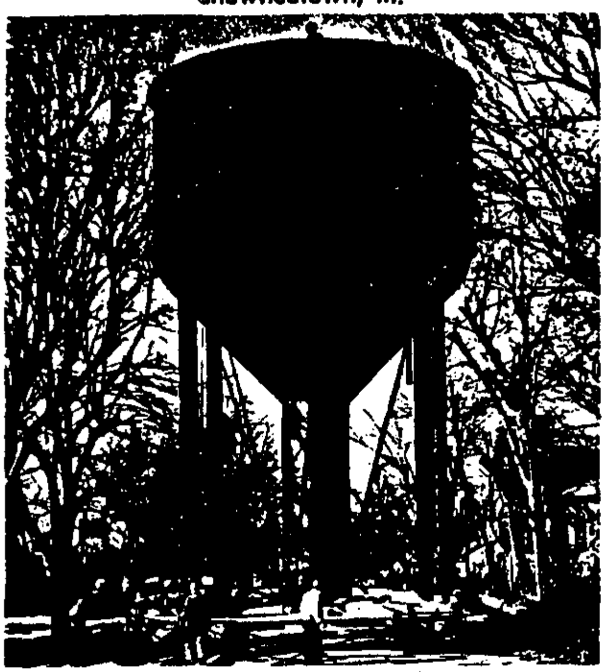


Entire town moved, including water tower and grain elevator
Shawneetown, Ill.

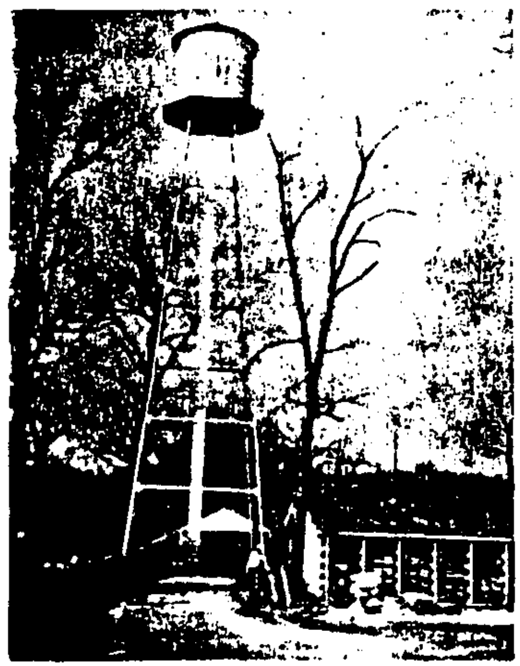
McCall Corporation
Dayton, Ohio



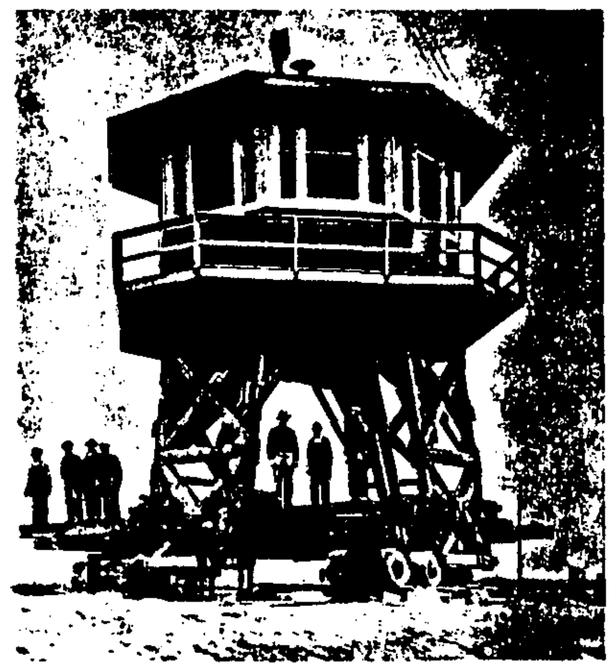
Mapes Molded Pulp Products
Griffith, Ind.



City Water Dept.
Glasgow, Mo.



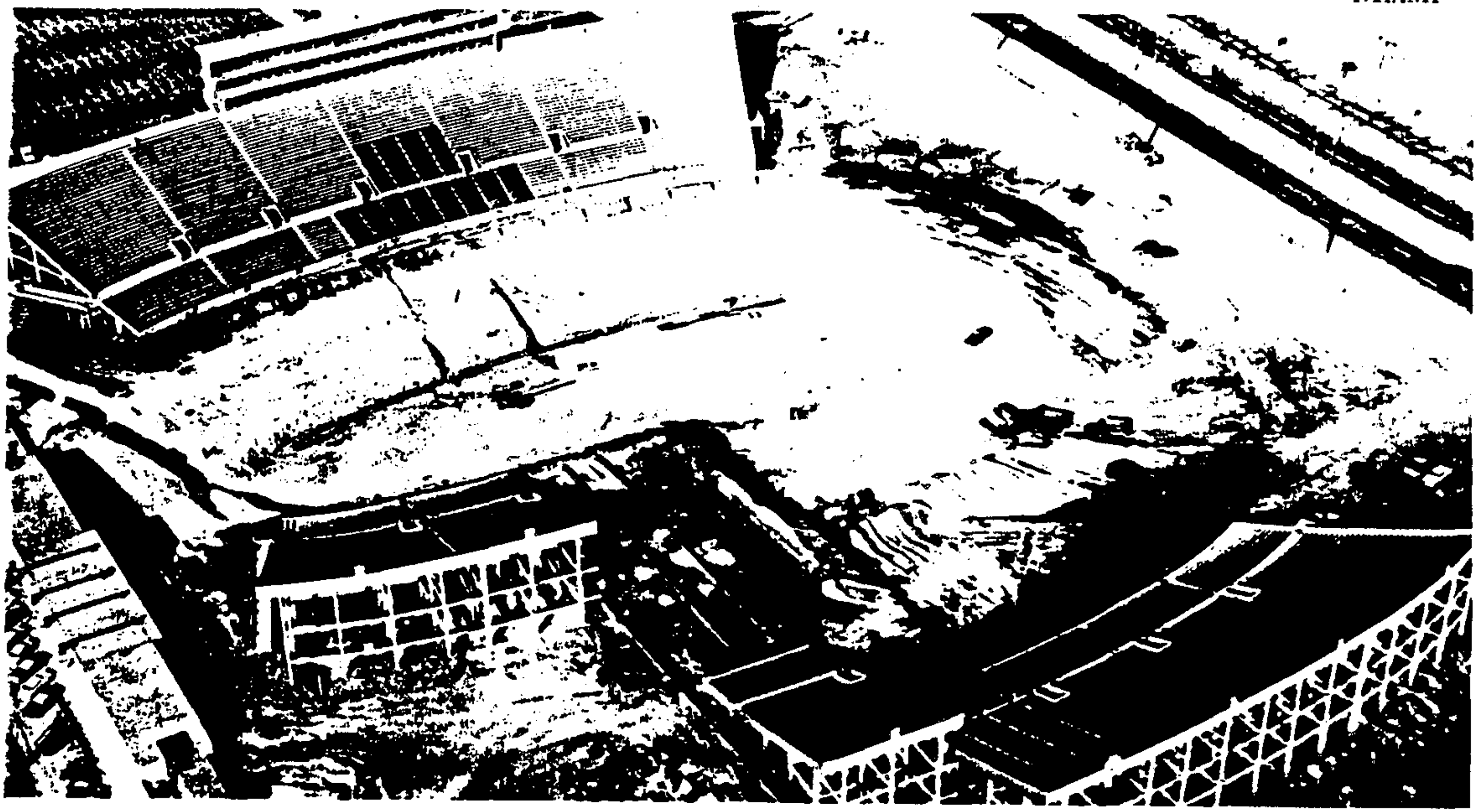
Bull Shoals Dam
Bull Shoals, Ark.



Como Internment Camp
Como, Miss.

LAPLANT-ADAIR CO.

INDIANAPOLIS MIAMI



Texas Tech Stadium, Lubbock, Tex., 2,620 ton stadium moved 225 ft. for stadium expansion

Moving - Raising - Shoring - Underpinning - Towers
Stacks - Bridges - Ships - Entire Towns Relocated

ALL PHOTOS DEPICT WORK PERFORMED BY THIS FIRM IN THE UNITED STATES AND CANADA —— WE FURNISH SURETY BONDS —— INSURANCE

Looking east along Schoolcraft Rd., the water tower is seen about a third of the way to its new site, a 30 ft. diameter of 8 ft. deep reinforced concrete with 18 in. thick walls. Subcontractor for the base was Harold Bjornstadt Const. Co., Troy.

150 ton tank moved in 3 days

Plymouth — In building the Pyramids the Egyptians moved huge granite blocks by placing rollers under them and hitching up a team of workers. A modern application of this concept was applied in Plymouth Township when it became time to move a 400,000 gal. water tower near Schoolcraft and Wilcox roads.

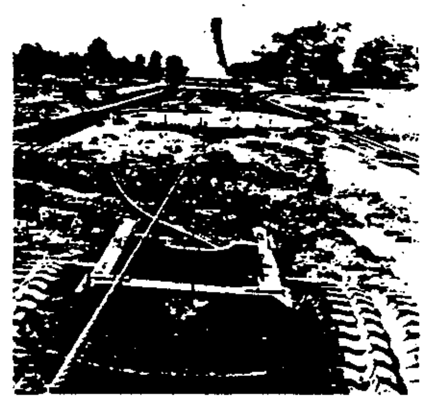
Due to the relocation of M-14, the tower had to be repositioned unto a new base some 500 ft. from its original site. Consulting engineering for the project was handled by Herald F. Hamill, PE, RLS, of Brender-Hamill & Assoc. Inc., headquartered here, and a $150,000 contract for the project was let to Ministrelli Const. Co. of Novi.

The actual moving of the tower was handled by a subcontractor, LaPlant-Adair Co. of West Palm Beach, Fla. The tower was jacked up from its old base and a platform consisting of 12 in. I-beams, three layers thick and approximately 60 ft. square, was constructed underneath it for the move.

At the new site, subcontractor Harold Bjornstadt Const. Co., Troy, built a new base for the tower of 8 ft. deep reinforced concrete, 30 ft. in diameter, with 18 in. thick walls.

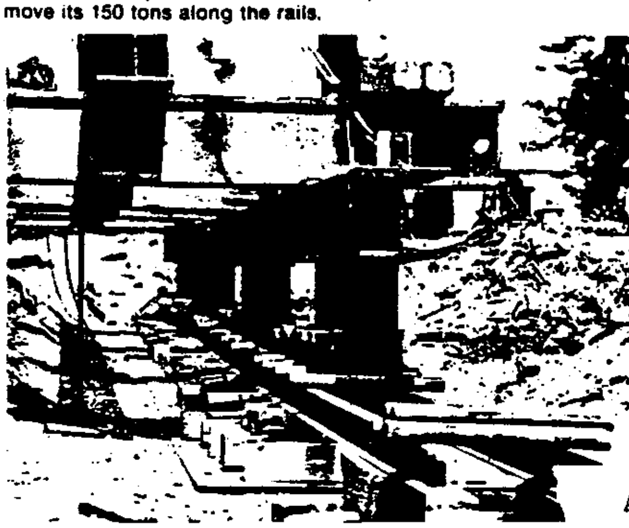
Four lengths of rails were laid for the move, two to each side of the platform, with a measurement of 50 ft. spanning the center of each set of rails. The platform and tower was jacked up and the first section of the railroad was built underneath it with rollers spanning the distance between the two rails in each set.

Instead of a team of hard muscled Egyptians, the winch off a Ford 900 truck was used to move the tower



Winching operations were handled with the use of a Ford 900 truck. Travel speed was four feet per minute and three days were needed to move the 400,000 gal. tower the required 500 ft. The distance between the centers of the two sets of tracks is 50 ft.

The platform for moving the water tank consisted of 12 in. I-beams, three layers thick, about 60 ft. square. Rollers were used to move its 150 tons along the rails.



As the tower is moved, tracks from behind it are taken apart and reassembled in front for the move forward. On the left is Mike Adair, project superintendent for the moving subcontractor, LaPlant-Adair of West Palm Beach, Fla.

along the rails at a rate of four feet per minute. As the tower was moved, the tracks behind it were taken apart and reassembled before it. When workers began to run out of rollers in front of the tower platform, the winching operation was halted, allowing rollers to be brought up from the rear and for the forward repositioning of the truck.

It took one week to prepare the water tower for the move and three days to bring it to its new site for installation.

Coordinator for the project for the Michigan Dept. of State Highways and Transportation was William F. Wines. William Duerr was the job superintendent for Ministrelli Const. and Mike Adair was the project superintendent for the moving subcontractor •

Huron Cement appoints Sheila Hoef sales rep.

Detroit — Mrs. Sheila Hoef has been appointed to the position of sales representative in the Detroit Sales District for Huron Cement Southfield.

Mrs. Hoef has been with the firm since 1958, where she began her career in the Pricing Dept. In June, 1970, she was assigned to the Detroit Sales Dept. of the company.

She is a graduate of Dearborn High School and has attended Henry Ford Community College.

July steel bookings

New York, N.Y. — According to reports complied by the American Inst. of Steel Construction Inc., July, 1976 bookings of fabricated steel amounted to 365,000 tons, an increase of 39% over the July, 1975 bookings.

A comparison by type construction to total bookings, July, 1976 versus June, 1976 shows industrial building down to 26% from 44%; utilities building rose to 26% from 16%; commercial building rose to 27% from 24%; bridges no change from 11%; public works rose to 8% from 4%; other rose to 2% from 1%.

Estimated July, 1976 shipments of fabricated steel were 283,000 tons - a decrease of 21% from the June, 1976 estimate. Of the total estimated industry backlog of 4,065,000 tons, about 40% or 1,626,000 tons are scheduled for fabrication within the next four months.

WASHINGTON

FED MONEY GOING SOUTH

The federal government's tax and spending policies are "causing a massive flow of wealth from the Northeast and Midwest to the fast-growing Southern and Western regions of the nation," says a research study produced by a Washington outfit, Government Research Corp., and there's liable to be a strong Congressional reaction to it.

The report says that so-called "donor states" are suffering erosion of their tax base and continued high unemployment even while the rest of the country is recovering slowly, and are facing the threat of cuts in public services that will reduce the quality of life there.

The study compared the federal benefits in the form of defense contracts, public works projects and Social Security payments with the number of tax dollars states sent to Washington. Those states in the sun belt in the West and South were enjoying the greatest population gains, less unemployment and improved per capita income levels. The loser states in the Northeast and Midwest had stagnant populations, severe to moderate unemployment, and by far the greater state and local tax burdens.

"Inequities are almost entirely accidental," the report noted, due to climatic and geographic factors for the most part, but the inequities are real, and are triggering a clamor from Eastern and Midwestern legislators to change federal policies to adjust the balance of payments. Among these are Rep. Michael J. Harrington (D.-Mass.), who is considering a lawsuit against the Economic Development Adm. for channeling money rather evenly across the states instead of concentrating it in areas where high unemployment and business failures indicate the greater need. One contradiction: the biggest beneficiary of federal funds was the District of Columbia, which received $7.67 for each dollar in federal taxes collected there.

GAS TAX PREDICTIONS

Higher state gas taxes and motor vehicle fees, but no early change in federal auto taxes, were foreseen by two HUFSAM spokesmen in recent days. HUF President Peter Koltnow told an industry group here that popular support for user pay-as-you-go taxes was encouraging, since fuel and operating costs are certain to go up in the years ahead. HUFSAM's PR Director Jack Martin reported at a Bismarck meeting this month that two states - Idaho & Kansas - have added 1¢ to their gas tax, while boosts were still being debated in 11 others. Minnesota Good Roads leader Bob Johnson said his state had added $147.5 million in new funding since 1975 - 2¢ in new gas taxes and $50 million in bridge replacement funds. However, a chilling comment from Texas was that if that state relied solely on the motor fuel tax for operating costs in the next two decades, it would need a 1¢ per gallon increase each year for the entire 20 years.

Koltnow told an IBTTA committee meeting that motor travel will increase 25% in the next 10 years despite the fuel shortage, but the future of long-distance vacation travel is still uncertain. Family transportation has cost about 12% of a family's budget in recent years, but this is sure to go up, even though people are keeping their cars longer. He also predicted a greater need for emergency road services as a result of more old cars remaining on the road.

NRC REVIEWS NUC POWER

The Nuclear Regulatory Commission has declared a moratorium on licenses for new nuclear power plants until it has completed a study of possible environmental dangers of reprocessing nuclear reactor fuel and handling radioactive wastes. This study will be completed sometime this fall. The decision followed a July court decision that NRC had not given enough consideration to these issues when licensing plants in Vermont and Michigan. Construction of both has been stopped pending investigation by a licensing board. NRC may decide to review the licenses of all 59 nuclear plants now operating in the U.S. after completion of its study and development of new guidelines for licensing.

SLIGHTEMS

HUD is weighing a plan to scrap its multi-billion dollar housing subsidy program in favor of a national block grant program, a sort of "housing revenue-sharing plan." It would cut miles of municipal red tape from lengthy application processes. Once proposed by Democrats in 1973, it could be used to spike expected criticism from campaigner Jimmy Carter.

Labor Secretary Usery has promised open shop contractors he will reconstitute the Wage Appeals Board to hear complaints re Davis-Bacon •

CAPE HATTERAS LIGHTHOUSE

EVENING CITIZEN
LACONIA, NH
D. 8,048

SEPT 23 1986

Debate Swirls Around Threatened Lighthouse

By TOM RINEHART
AP Writer

BUXTON, N.C. — At the foot of the 116-year-old Cape Hatteras Lighthouse, pounding waves wash away 11 feet of beach a year. Just as unrelenting is the debate over how to save the spiral-striped symbol of the wild North Carolina coast.

The U.S. Army Corps of Engineers plans to begin building a revetment and seawall around the 208-foot tower as early as January, anticipating it will become an island as the Outer Banks shoreline recedes over the next 50 years.

But that $5.6 million plan has stopped neither the people trying to build up the beach with artificial seaweed nor those who want to move the nation's tallest lighthouse inland.

"As soon as they build the wall it's going to seal its fate," said Orrin Pilkey, a professor of geology at Duke University and a member of the Move the Lighthouse Committee. "Once it moves offshore, it's doomed."

Pilkey said the seawall and the revetment, an underground structure, would not stand up to storms, adding that seawalls actually hasten erosion.

"The only way to save the lighthouse is to move it," Pilkey said.

"That's utterly ridiculous," said Hugh Morton, acting chairman of the Save the Lighthouse Committee. "There have been cracks discovered in the lighthouse ... and it extends more than 50 feet below the ground."

Morton's group wants to keep the lighthouse where it is, checking the beach erosion with sand-catching synthetic "seaweed" rather than a seawall.

In 1982, the committee spent about $165,000 to place 5,000 units of artificial seaweed around the beach to settle the water-borne sand into bars. Another installation costing $81,000 is planned soon. The sandbag-anchored units of five-foot-long fabric strips have already filled a deep lagoon to the south of the lighthouse that could have been the greatest threat if a storm came from that direction, he said.

The seaweed plan, he argued, "could build enough beach to put (the University of North Carolina's) Kenan Stadium and Charlotte Motor Speedway out in front."

But officials of the National Park Service, which manages the lighthouse as part of the Cape Hatteras National Seashore, say it can't be proved that the artificial seaweed is doing any good.

"It was uncertain exactly what could be attributed to the product," said Kent Turner, the park service's specialist on the lighthouse beach. "There was some ... buildup along a pretty wide band of beach after the product went in."

Even so, the park service has accepted the Corps of Engineers' recommendation for the seawall and revetment. All that's needed are the final specifications and approval of funding legislation pending in Congress.

David Fischetti, an engineer who heads the Move the Lighthouse Committee, said neither the corps nor the park service gave enough consideration to his group's idea.

Move the Lighthouse estimated in 1980 that it would cost $2.75 million to cut through the lighthouse at its base, lift the 2,800-ton structure onto a concrete-and-steel track and move it about half a mile southwest to an area that would be stable for at least 200 years.

"So many projects have been done around the world that were much more difficult than this," Fischetti said. Czech engineers in 1975 spent $15.3 million to move a 12,000-ton cathedral 800 yards to make way for a coal mine, and in 1967, Italian engineers moved the 300,000-ton Egyptian temples of Abu Simbel to make way for rising Nile waters behind the Aswan Dam.

Moving the lighthouse probably would cost much more than Fischetti thinks, say officials of the corps and the park service, noting that it would have to cross a marsh.

"You can get into very costly structures just to build the roadway," said Tom Jarrett, chief coastal engineer for the corps' Wilmington branch.

The National Aeronautics and Space Administration, which has vehicles that move massive rockets, advised the park service in the late 1970s that moving the lighthouse would cost many times what Fischetti estimated, said Jay Gogue, former regional chief scientist for the park service and now a researcher at Clemson University.

Trying to move the lighthouse would not only threaten to destroy it, it would also change its historical significance and require costly changes on navigation charts, he said.

Jarrett disputed Pilkey's contention that the seawall-revetment structure could not withstand years of storms.

"We've done extensive testing under very severe conditions," he said. "It's a very substantial structure. The massive concrete wall reflects waves, and underneath there's a large, extensive rubble mat that extends 100 feet out in front of the seawall — these are big stones. It's designed for a future shoreline 100 years from now, when the floor will be 10 to 12 feet below the existing ground."

But Fischetti said the park service should consider the asthetic effects of a tall wall around the lighthouse, as well as the boost to tourism that could come from the sheer spectacle of moving the lighthouse.

"It would capture the imagination of a lot of people around the country."

APPENDIX 3

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BIBLIOGRAPHY

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